A. P. Forndran.

The Technical Educator

Fig. I.

The Solar Spectrum.

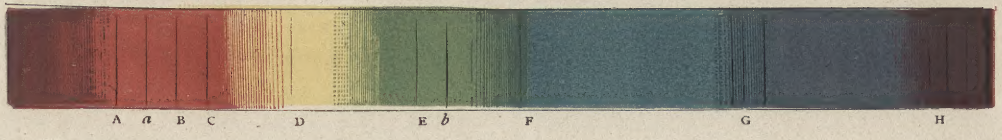
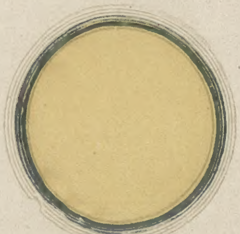


Fig. III.



Subjective Colour.

Fig. IV

Colour as related to idea of Distance.

Fig. II.

The Primary, Secondary, and Tertiary Colours.

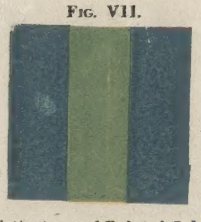
Fig. V.

Effect on Colours of Apposition.

Fig. VI.

Mixture of Colours by Apposition.

Fig. VII.



Indistinctness of Related Colours in contact.

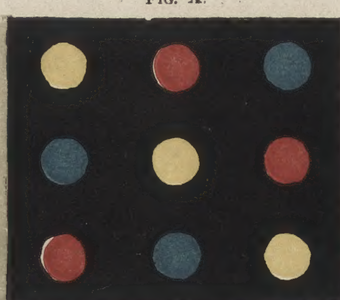
Fig. VIII.

Effect of Black and White in separating Colours.

Fig. IX.

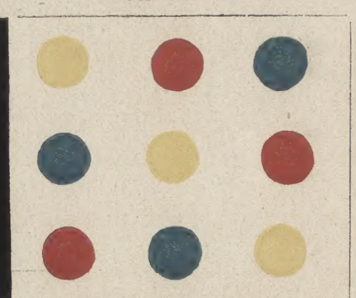
Effect of a Grey Ground on Colours.

Fig. X.



Effect of a Black Ground on Colours.

Fig XI.



Effect of a White Ground on Colours.

See Lessons on Theory of Colour.

THE A. P. Forndrew.

TECHNICAL EDUCATOR:

An Encyclopædia

OF

TECHNICAL EDUCATION.

VOLUME I.

CASSELL PETTER & GALPIN:

LONDON, PARIS & NEW YORK.

CASSELL, PETTER, AND GALPIN, LA BELLE SAUVAGE YARD E.C.

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THE

TECHNICAL EDUCATOR:

BEING THE TECHNICAL SERIES OF "CASSELL'S POPULAR EDUCATOR."

INTRODUCTION.

BEFORE entering upon the course of lessons which we are about to lay before our readers in THE TECHNICAL EDUCATOR (which is intended to furnish a *practical* sequel to the theoretical lessons contained in THE POPULAR EDUCATOR, and to which work indeed it forms a necessary supplement), it appears desirable to state what is understood by Technical Education, and to give some general idea of the system upon which it is our intention to proceed.

Technical Education, as we have already explained in the address "To our Readers" in the concluding volume of THE POPULAR EDUCATOR, means literally education in any special art, and in this sense, of course, it is capable of almost the widest application. There is, in fact, no calling in life, no profession, vocation, or employment, from statecraft and diplomacy downwards, through the long lines of brain-work and hand-work, whose followers do not require a technical education peculiarly suited to it to enable them to pursue it with the best results to themselves and the largest amount of benefit to others. At the present day, however, the term "Technical Education" is not generally understood in so wide a signification, but it is confined to special instruction designed to enable men who live by hand labour to apply to their handicraft the leading principles of science which bear more especially upon it.

Without going to the length of giving a detailed list of all the different classes of hand-workers to whom this special kind of art instruction may be of benefit, we may at least indicate in general terms the course of instruction we purpose to adopt in these volumes. The subject which primarily affects those who would receive benefit from Technical Education, is DRAWING in its practical application to the various Constructive Arts, as well as to DESIGN and ORNAMENTATION. Papers on these subjects, together with the kindred ones of PERSPECTIVE, PROJECTION, and PRACTICAL GEOMETRY, will run through the volumes of THE TECHNICAL EDUCATOR, those on TECHNICAL DRAWING for Trade Purposes embracing Drawing for Carpenters and Joiners, Masons, Metal Workers, and several others. DESIGN will be treated under its various conditions and in its different styles, both as regards purity and correctness of form, and harmony and balance of colour. With regard to the latter portion of the subject, special information will be given in a series of papers upon the THEORY OF COLOUR. The subject of DRAWING is in one branch intimately connected with that of PRACTICAL BUILDING CONSTRUCTION, which will form another portion of our series: these will treat of such points as the principles of construction generally, of scaffolding, and the strength, resistance, and applicability of different building materials.

The principles of Mechanics and Machinery have already been laid down in THE POPULAR EDUCATOR. In the present volumes we shall supplement this information by describing the practical application of these principles to the machinery, tools, and agricultural implements in ordinary use. Special papers will also be devoted to the STEAM-ENGINE, in its various applications to locomotive and mechanical purposes. A set of papers upon the principles and practice of ELECTRIC TELEGRAPHY will form a practical continuation to the information already given on that subject in THE POPULAR EDUCATOR. Another very important subject which will form part of our scheme is CIVIL ENGINEERING, as well as the kindred one of MILITARY ENGINEERING and FORTIFICATION, and also what may be termed AGRICULTURAL ENGINEERING, the drainage and irrigation of land, and the making of fences and roads.

A portion of our space will be devoted to an account of the various ANIMAL, VEGETABLE, and MINERAL PRODUCTS used in Trade, and the processes of their manufacture from the raw material into articles of utility and ornament. Closely allied to these subjects is PRACTICAL CHEMISTRY, which will be treated of in its application to Trade Purposes and Manufactures, and also to Agriculture. The course of instruction we have thus laid down will be sufficiently comprehensive to include every branch of handicraft work; but in addition to this, some special branches of manufacture will also receive separate treatment; among these we may mention the MANUFACTURE of OPTICAL and PHILOSOPHICAL INSTRUMENTS, and WEAPONS of WAR.

We have now enumerated some of the subjects in which direct instruction will be given, and we have thought it advisable to add to them some others which will form a very interesting portion of the Work, being at the same time of a character both practical and instructive. Among these will be given descriptions of the PRINCIPAL SEATS OF INDUSTRY in this and other countries; BIOGRAPHIES OF NOTABLE INVENTORS AND MANUFACTURERS, with accounts of their work; a sketch of the PROGRESS AND PRACTICE OF TECHNICAL EDUCATION; and an account of the MUSEUMS and SCHOOLS OF DESIGN which have been already established for aiding Technical Education in this country.

BUILDING CONSTRUCTION.—I.

INTRODUCTION.

THE purpose of the present course of lessons is to give a general knowledge of "Building Construction," the special branches of which will be separately treated in subsequent articles.*

The instruction given in this course is simplified as much as is consistent with the proper working out of the subject, whilst the illustrations are rendered as clear as possible, in order that they may serve not only as illustrations of construction, but also as drawing copies—of which a further series will be given in the lessons on "Technical Drawing."

The student is strongly advised not to merely read the text and *look* at the examples, under the idea that the distinctive forms will be thus impressed on his mind, and that he will be able to reproduce or apply them when required. Long experience has shown us that this plan is unsafe, and that lessons of this kind cannot be merely read as tales; though in these, too, it is now admitted that the illustrations of the events depicted serve to fix the acts, actors, and scenes on the memory. This purpose may to a certain extent be accomplished by merely seeing the drawings; but our object is twofold. We wish not only to teach the student to *read* a new language, and that language a universal one, but to *speak* it fluently. We wish to teach a workman not only to be able to work from a drawing, but to make one. This applies not only to masons and bricklayers, but to all artisans; and if once the pleasure of being able to sketch with a piece of chalk from his pocket, or his rough flat pencil, so as to satisfy and please his employer, is felt, we have no fear but that the artisan will continue his study of drawing with increased interest.

In plain words, we wish these lessons to afford mental study combined with manual practice, so as to accustom the student not only to think, but to act—a glorious combination which the education of the workers is most likely to bring about. The system therefore advised is that the student should first read the section carefully, referring to the cuts, and accurately observing the lettering. The illustration should next be drawn to a larger scale, and lettered to correspond; and then the references or description written underneath it: not necessarily the whole text, but an abstract of the principles. The student will then be able to look over his drawings occasionally, and will see the constructions at a glance; these glances will serve as reminders, and each will awaken a chain of ideas which may for the moment have glided away, but which such a gentle touch may call back again.

It is further necessary to remind the student that the constructions treated of in these lessons, and in those diverging from them, are all more or less dependent upon the geometrical principles, forms, developments, and projections which are exemplified in other lessons given in these pages; and he is urged not to rest satisfied with merely *copying the diagrams*, but to vary the studies, *to apply the principles*, and to attempt, however humbly, to design for himself. Let him look at the revival of architecture now going on around us, and reflect that this is being accomplished by the careful and conscientious study of the sciences upon which the glorious edifices of old were constructed, not by merely copying them; and therefore it is that we would have the student throw his whole spirit into his vocation, and not merely to hew stone or cut wood, but to remember the words—

> "Stamp each stone with earnest feeling,
> In the rock thy soul revealing."

Thus did the men of olden time. Their heart and soul were in their work, and when we look on it in the cathedrals and in the museums, with our spirit enchained and enraptured, we fail to ask, "How much did it cost?" for, to the man who would do his duty, the question, "How much shall I get for it?" must for the moment sink before the one great resolution, "I will do my best." But the artisan will ask, "Will this bring me wages?" and we unhesitatingly answer, "Yes, it will;" for we may fearlessly assert that never in the whole history of labour has there been a period when the workman has been deemed more worthy of his hire, or when greater efforts have been made, first to teach the artisan, and then to show appreciation of his work, than the present. Let him but show that he possesses, in the words of Reynolds, "a love of art, and a desire to excel," and he may be assured that he will not want encouragement for his efforts.

* It will be of advantage to the student, if he has not already done so, to go through the papers on "Practical Geometry" which have appeared in THE POPULAR EDUCATOR. He must also follow the further development of that subject, together with the lessons on "Projection," which will appear in these pages.

OF THE DRAWINGS REQUIRED FOR BUILDING PURPOSES.

The drawings required for the general purposes of building may be classed under four heads, viz.:—

PLANS.	ELEVATIONS.
SECTIONS.	WORKING DRAWINGS.

To these must be added "Perspective Drawings," which, however, are not used in absolute construction, but are intended to represent the building when seen from various points of view; and "projections," by which the widths, etc., of elevations, and the true shapes of the sections are obtained.

The terms *plan*, *elevation*, and *section* are fully explained and practically demonstrated in the lessons on "Projection," which in its turn is based on the construction of geometrical forms, treated of in the lessons on "Practical Geometry" in the POPULAR EDUCATOR.

It must be obvious that the course of instruction would be impeded were we to repeat the definitions and examples already given in explanation of these terms, before entering on our present subject. We would therefore earnestly advise the student to study the lessons referred to; not to be content with the mere possession of the pages, but to *work* each example carefully; by this means he will have laid (to use a term adapted to our theme) a firm foundation, the benefits of which he will experience during the whole course of his subsequent studies.

We will merely, then, remind the reader that the plan of a building, etc., is the exact form of the ground on which it stands or which it overhangs. (See lessons on "Projection.")

Plans are spoken of as—

1. *Block Plans.*—These show the mere outlines of the buildings, and their position in relation to the surrounding objects. In most cases the block plans are accompanied by drawings showing the levels of the ground and neighbourhood, the drains, gas and water mains, already existing, and the method by which the new works are to be connected with the old. These drawings are, in fact, maps of the whole property, on which the general shape and position of the buildings are marked.

2. *Excavation Plans.*—This term is almost self-explanatory. These drawings give the exact shape of the excavations—that is, of the hollows to be sunk for the required buildings. The term is derived from *ex*, "out," and *cavus*, "hollow" (Latin). They show the trenches to be dug for the walls to stand in, and also give the plans from which the works below ground, such as cellars, etc., are to be excavated.

3. *Basement Plans.*—These show the foundations and works, up to the ground-line or level of the ground.

4. *Floor Plans*, sometimes called *Chamber Plans.*—These show the exact disposition of the rooms, etc., on each floor, the staircases, etc. The beginner might at first think that one drawing could show all this; but the idea would be erroneous, because on the ground floor some apartments, such as store-rooms, larders, etc., or other outbuildings might project from the house and cover more ground than the upper floors; secondly, the rooms in upper floors might be divided by partitions, which would make their plans different from those below, although covering the same area. Under this head, therefore, would be comprehended the *ground-floor plan*, showing the dining-rooms and drawing-rooms (where the latter are on the ground floor), the entrance hall, staircase, etc.; the *chamber plans*, showing the bed-rooms, dressing-rooms, and bath-rooms (and, of course, such a plan would be necessary for each floor); and the *attic plan*, showing how the space is apportioned in the highest floor of the house.

5. *Roof Plans.*—These show the exact manner in which the building is to be covered, and the gutters by which the water is to flow to the heads of the spouts by which it is to be conveyed away. It is usual to show parts of the roof plan uncovered, or naked; that is, with the slates or tiles removed, so as to allow of a plan of the roof timbers being shown.

ELEVATIONS.

Elevations are exact geometrical views of each side of the building. By the term "geometrical view" is meant a drawing where every part is represented as it really *is*, without any attempt at showing the sides or parts which would be seen if the building were looked at from any particular point of view; for in a perspective drawing, the various parts, such as windows, doors, mouldings, etc., would be rendered smaller as they become more distant, and thus the drawing could not be measured from; but in an elevation, the eye is supposed to be *exactly* in front of every part of the side of the building which is to be delineated, so that all the sizes and forms remain unaltered. As the subject of projecting elevations from given plans will be fully treated of in our lessons in "Projection," it is unnecessary to enter further into it in this place, especially as several opportunities will occur in the course of our study, in which the principles taught may be practically applied.

It will be readily understood that as many elevations are required as there are sides to the building; thus, in erecting a detached villa—that is, one which stands alone—it will be necessary to prepare the *front elevation*, the *back elevation*, and two *side elevations*; whilst for a house in a street, situated between two others, only the front and back elevations would be required.

On all the plans and elevations figures are placed to show the measurements. Those on the plans give the *widths* of the different parts, whilst those on the elevations give for the most part the *heights*; in order that it may be clear to which parts the dimensions apply, an arrow-head is placed at each extremity. These are connected by a dotted or coloured line. This is broken off in the middle, and the necessary figures inserted.

Of course, plans and elevations are drawn very much smaller than the real size, yet all the parts are represented in such accurate proportion, that the figures may be readily translated to the required dimensions; this is called "working to scale," and the proportion in which the drawing is made is always stated on it. Thus you will notice in the margin, "Scale, $\frac{1}{8}$ inch to a foot;" this means, that every part of the drawing which measures $\frac{1}{8}$ of an inch is to be 1 foot long in the building; and as there are *eight-eighths* in an inch, and twelve inches in a foot, it will be clear that the drawing is one ninety-sixth of the real size. When one dash (′) is placed over a figure, it means that that figure represents *feet*; whilst two dashes (″) mark *inches*; and it is no doubt known to the student that × means "multiplied by," or, as it is generally termed, "by;" thus, if a room is marked 14′6″ × 12′3″, it means that it is to be fourteen feet six inches long, *by* twelve feet three inches wide. The mode of making scales will be shown further on.

SECTIONS.

The drawings next required are called *sections*. The study of "Projection" will show what sections really are, and how they are obtained. It is, then, only necessary here to give a very simple definition of them, for it must be clearly understood that Projection is not to be *taught* in the present lessons, but *applied*; and therefore students are urged to take up that study either prior to (which is the more advisable), or together with this, otherwise they will be likely to become truly "*mechanical* draughtsmen," that is, men who simply draw *mechanically*, who work from a *copy*, and rightly or wrongly measure and draw the lines because they are in the drawing before them, thus becoming mere drawing *machines*; whereas the study of Projection will teach them to obtain an elevation from a given plan and other data, and to work out the sections according to the required position. A section, then, is the form which would be presented if an object were cut in any given direction and one part removed. Thus a plan may be said to be an *horizontal* section; that is, the form which would be presented if a large knife were passed through a building parallel to the floors, and the upper portion were removed. Sections are, however, usually understood to mean vertical (or upright) cuttings, generally parallel to one of the elevations; thus, a *longitudinal* section is a cutting parallel to the front, while a *transverse* section is a cutting *across*; viz., parallel to the sides of the building. Sections need not necessarily be parallel to either side, but may be taken in any direction that may be required, their position being shown by a line on the plan.

Now the section of a *solid* body shows just the shape of the cutting, or, in common terms, the "slice" taken on a given line; but if the object were hollow, its internal surface would be presented to view; thus, if a house be supposed to be cut from back to front, the whole of the interior structure will become visible; and thus, by giving sectional drawings taken on different lines, the entire modes of construction of the floors, roofs, staircases, etc., are shown, as are also the manner in which the rooms are placed over each other, and the walls and chimney stacks are carried up.

WORKING DRAWINGS.

Next we come to the *working drawings*, or as they are sometimes called, the *detailed drawings*. These are to show *exactly* all the detail of the various parts, which could, of course, only be rendered on a very small scale in the general drawings. Working drawings, therefore, are made much larger; it is necessary, in fact, that the drawings of some of the parts be made of the *real* size, in order that the detail may be perfectly intelligible to the workman, so that drawings may be made for other parts which are to fit exactly to them.

Working drawings are required not only for the builder, but for the purposes of the decorator as well, in order that the ornamentation may be designed so as to be adapted to the size and form of the surface to be covered. They are also necessary for the mason, in order that from them he may make his *templets*, or pieces of metal, cut to the exact shape of the section, etc., of the moulding or string course, and that by them he may make all the single pieces of stone which are to form tracery, of the exact form and size required.

Detailed drawings are also required in making the patterns in wood from which the iron girders and other castings are made, and for the carpenter and joiner, to show the method of framing-in the doors, windows, shutter-boxes, etc. It therefore becomes necessary that a separate set of drawings be provided for each trade.

When it is intended that any part of a drawing is to represent in section, it is usual to cover such part with lines drawn at an angle of 45°. This is easily done by placing the T-square with its cross-head against the left-hand edge of the drawing-board, and moving the set square (of 45°) along the edge of the blade as each line is drawn. The section lines should not be placed too closely together, and if the drawing is to be coloured, the colour should be applied first, and allowed to dry thoroughly before the section lines are drawn; for if the lines have been drawn first, the colour would be likely to "wash up" the Indian ink, and so cause a smeared and blotched appearance. The lines which represent the sections of stone, bricks, etc., are *straight*, but those which are to show the sections of wood are so placed that they may either represent the grain or the curves which are seen in the ends of timbers, and which are parts of the rings of woody fibre of which the wood is formed. Care must be taken that none of these effects are overdone. The student must remember that he is not making a picturesque drawing (and even if he were, excessive elaboration of such detail would be out of place), but that "trade drawings," the "drawings of the workshop," must be purely indicative, so that they may show at a *glance* the different materials of which the object is to be constructed. This purpose is much assisted by tinting each part with the colours which are generally understood to represent the various materials.

A few plain instructions on the method of colouring drawings, and the colours used to express the various materials, will be given in the lessons on "Technical Drawing."

ANIMAL COMMERCIAL PRODUCTS.—I.

INTRODUCTION.

In the animal as in the plant world, we find progressive organic development, boundless diversity of structure, and a beautiful subserviency of means to ends. The highest type of life is Man. The different grades of organisation have their purposes to fulfil, and each animated being has its own position independent of the rest, yet subordinate with reference to others of more complicated form and frame, especially with reference to man, for whose benefit all seem to exist.

With the scientific classification and description of living creatures has lately arisen a desire for a scientific designation of

their economic uses, and a statement of their comparative commercial value, in order that the appliances of social life and the claims of civilisation may advance with the progress of inquiry and the diffusion of knowledge.

Energy and skill are alike taxed for the discovery of new properties in the animal, the vegetable, and the mineral kingdoms; or for the further utilisation of properties long known. A careful study, then, of the contents of a collection like that in the South Kensington Museum, together with the greater variety passing through our Custom-house from the cargoes of all nations, must be highly important, while it can hardly fail to be interesting.

There is but one path for the successful pursuit of knowledge so valuable and so honourable—the path of science; for science is the track of truth, plain in all simplicity, yet revealing the symmetry and the beauty of the works of the Creator.

ZOOLOGICAL CLASSIFICATION.

Naturalists have arranged the animal kingdom into two grand divisions.

I. VERTEBRATA (Latin, *verto*, I turn), or vertebrated animals, having the central portion of the nervous system, or the brain and spinal cord enclosed, the former in a cavity called the cranium or skull, and the latter in a canal composed of a succession of united vertebræ, or bony segments, or, as in some fishes, of cartilage.

The vertebrated animals are arranged in five divisions or classes:—

1. *Mammalia* (Latin, *mamma*, a teat).—Animals which possess mammary glands and suckle their young, bringing them forth alive. Examples: the monkey, ox, seal, elephant, and whale.

2. *Aves* (Latin, *avis*, a bird).—Oviparous vertebrated animals covered with feathers and organised for flight. Examples: the ostrich, swan, pheasant, and eagle.

3. *Reptilia* (Latin, *repo*, to creep).—Cold-blooded vertebrated animals, covered with scales or hard bony plates, terrestrial or aquatic, air-breathing, and endowed with extraordinary powers of endurance under abstinence, or against bodily injury. Examples: the turtle, snake, crocodile, lizard.

4. *Amphibia* (Greek, *amphibios*).—Fish-like in the early period of their existence, breathing exclusively by gills, and having a two-chambered heart, finally becoming air-breathers, acquiring lungs and a three-chambered heart, losing wholly or partially their piscine character, and becoming more or less terrestrial. Examples: the frog, toad, and proteus.

5. *Pisces* (Latin, *piscis*, a fish).—Oviparous vertebrated animals having a branchial respiration, a covering of scales, and an organisation for life in the water. Examples: the sturgeon, cod, and herring.

II. INVERTEBRATA, or animals destitute of a cranium or skull, and a vertebral column.

The invertebrated animals comprise four sub-kingdoms:—

1. *Mollusca* (Latin, *mollis*, soft), or soft-bodied animals, popularly known as shell-fish. Examples: the oyster, pearl-oyster, and mussel.

2. *Annulosa* (Latin, *annulus*, a ring), or ringed animals. Examples: crabs, leeches, and insects.

3. *Radiata* (Latin, *radius*, a ray), or radiated animals. Examples: the sea-anemone and red coral.

4. *Protozoa* (Greek, *protos*, first, and *zoön*, animal), or first animals. Example: the common sponge.

We now purpose to take up the various animal products in succession according to the above zoological arrangement. We begin with the highest and most useful class of Vertebrata, or the

PRODUCTS OF THE CLASS MAMMALIA.

This class comprises twelve orders, viz.:—

1. *Bimana* (Latin, *bis*, twice, and *manus*, the hand), or two-handed animals. Example: man.

2. *Quadrumana* (Latin, *quatuor*, four, and *manus*, the hand), or four-handed animals. Example: the monkey.

3. *Cheiroptera* (Greek, *cheir*, the hand, and *pteron*, a wing), or hand-winged animals. Example: the bat.

4. *Insectivora* (Latin, *insecta*, insects, and *voro*, I devour), insect-eaters. Examples: the hedgehog, mole, and shrew.

THE ORNITHORHYNCHUS, OR DUCK-MOLE OF AUSTRALIA.

5. *Carnivora* (Latin, *caro*, *carnis*, flesh, and *voro*, I devour), flesh-eaters Examples: the lion, tiger, fox, and ermine.

6. *Cetacea* (Gr. *ketos*, a whale), or whale-like animals. Examples: the porpoise and whale.

7. *Pachydermata* (Greek, *pachus*, thick, and *derma*, skin), or thick-skinned animals. Examples: the elephant, horse, and pig.

8. *Ruminantia* (Latin, *ruminare*, to ruminate), ruminating animals. Examples: the stag, ox, and sheep.

9. *Edentata* (Latin, *edentatus*, without teeth), toothless animals. Examples: the sloth and armadillo.

10. *Rodentia* (Latin, *rodere*, to gnaw), gnawing animals. Examples: the squirrel, rat, rabbit, and hare.

11. *Marsupialia* (Latin, *marsupium*, a pouch), or pouched animals. Examples: the kangaroo, opossum.

12. *Monotremata* (signifying with one orifice or outlet), beaked, non-placental mammals. Examples: the echidna, or porcupine ant-eater, and the ornithorhynchus or duck-mole of Australia, to which country these monotrematous animals are peculiar.

The Mammalia, living or dead, supply us with food in the form of flesh and milk: also with fur, wool, skins, hides, horns, hair, hoofs, fats, oils, bone, ivory, etc. In some instances every part is available—as, for example, in the horse. Leather is made from the skin; the hair is manufactured into hair-cloth and bags for crushing seed in oil-mills; the flesh furnishes food for dogs, poultry, and even men; the intestines, a covering for sausages; glue and gelatine are formed from the tendons; knife-handles and phosphorus from the bones; and buttons and snuff-boxes from the hoofs.

I. FURS.

We derive furs from all the orders of the Mammalia, with two exceptions—Bimana and Cetacea. Man and the whales are well

known to be smooth-skinned animals. It is, however, the Carnivora and Rodentia principally which supply the market with furs. All our furs, both home and foreign, are either felted or dressed; the former are used in the manufacture of hats, the latter as articles of clothing. Fur is one of the most perfect non-conductors of heat, and therefore, if properly prepared, makes the most comfortable clothing that can be worn in cold climates. We find the animals there provided by Nature with this substance for their own protection, and therefore man has adopted it as the most suitable clothing for himself. In the prepared state skins are called furs; without preparation, *peltry*.

The hunter, as soon as the animal is captured and killed, strips off the skin, and hangs it up to dry, either in the open air or in a warm room. If the skin is well dried and properly packed, it may be sent to any distance, and will be received in good condition; but if any moisture is left in the skin, or if it becomes exposed to damp on the voyage, putrefaction ensues, the hair falls off, and it is unfit for use so far as the furrier is concerned. A minute examination of the skins received is therefore the first thing to be done; the grease is removed by steeping them in a liquid containing bran, alum, and salt, and by washing and scouring them; and the oil is extracted from the fur with soap and soda. By subsequent treatment, each skin is tanned and converted into thin leather. It is now washed in clean water and dried, and is then ready to be made up into articles of dress.

Felting is a process by which the different kinds of hair and wool are interlaced or intertwined, so as to form a close compact texture or mat. The felting capabilities of fur depend on the peculiar structure of the hair. Hair capable of felting has its surface covered with little serratures, which may be seen with the microscope; and the felting consists in simply entangling these serratures with each other, and so matting the hairs together. Hair which is devoid of this serrated structure will not felt.

The felting furs are confined to a few animals, such as the hare, rabbit, beaver, etc. These animals have two kinds of hair: a long and coarse kind, forming their visible external covering, which does *not* felt; and a shorter, finer, and more abundant kind, which lies close to the skin, and is called the fur, and which does felt easily. When the skins are intended to be felted, these long hairs are first removed, either by being plucked out, or by very careful shearing. In the case of the beaver and rabbit, the long hair is pulled out with a short knife, the thumb of the operator being protected by a leather shield. The long hairs thus removed are of no use to the hatter, but are sold for stuffing chairs. The fur is then cut from the skin in a light fleecy mass, and the flocks are tossed about by the strokes of a vibrating string or bow, until matted together into a thin sheet of soft spongy felt; a second sheet is pressed upon it, and then a third, until the required degree of strength and thickness of felt is obtained. The following are the most important of the fur-bearing animals:—

QUADRUMANA.

The chief monkey-furs imported are those obtained from the *howlers*, the largest of the New World monkeys. They are made up into muffs.

CARNIVORA.

These animals, next to the monkeys, are the most closely allied to man in organisation. Naturalists have divided them according to their mode of progression, which depends on certain peculiarities in the structure of their feet, into three leading groups:—

1. The *Digitigradæ*, or finger-walkers (Latin, *digitus*, a finger, and *gradior*, I walk), from the habit of walking on their toes. Examples: the lion, tiger, and cat.

2. *Plantigradæ*, or sole-walkers (Latin, *planta*, the sole of the foot), because applying the whole or the greater part of the sole to the ground when walking. Examples: the bear, racoon, wolverine, and badger.

3. *Pinnigradæ*, or fin-walkers (Latin, *pinna*, a fin or feather), having their feet well adapted for progression through the water, by an expansion of the skin or web between the digits, and also for some slight degree of progression on land. Examples: the seal and walrus.

I. DIGITIGRADÆ.

This division of the Carnivora includes the family *Felidæ* (Latin, *felis*, a cat), so named by Linnæus, because an excellent example is furnished in the common domestic cat. These are characterised by the strong, sharp, retractile talons with which all their toes are armed; they have teeth to correspond, peculiarly adapted for destroying other animals, and for tearing, dividing, and crushing flesh. Their sight is keen, to enable them to discern their prey, and they have great power of dissembling, so as to be able to lure their victims to destruction. It is most fortunate for mankind that these formidable animals have not the instinct of sociality; otherwise, what could withstand a troop of lions or tigers hunting in concert like wolves? The most celebrated species of this genus is—

The Lion (*Felis leo*).—This magnificent animal is distributed over the African continent and the southern parts of Asia. The long flowing mane of the male gives him a majestic appearance. His courage and strength are both indisputable, but he is as genuine a cat as the tiger, and quite as bloodthirsty and cruel in his disposition. About one hundred lion skins are annually imported into this country, chiefly from Africa.

WEAPONS OF WAR.—I.

BY AN OFFICER OF THE ROYAL ARTILLERY.

INTRODUCTION.

In order properly to appreciate the various improvements which through successive centuries have been introduced in weapons of war, and of which we see the combined results in the perfected arms with which the modern soldier is provided, it is essential first to recognise distinctly the object which weapons are required to fulfil. In this way alone can we hope to obtain a firm grasp of the relative merits of particular types and classes of arms, and of the considerations which have recommended this simplification and that modification, which have determined the rejection of one weapon and the introduction of another.

What, then, is the use and object of weapons of war? What principle has ever governed the advance of this branch of the world's industry and ingenuity? The answer to these questions is best furnished by a brief reference to the general history of the subject. The theoretical starting-point is that remote epoch when man attacked his enemy and his prey with the weapons with which Nature had provided him. We say "theoretical," because the actual existence of such an epoch is extremely doubtful, and in any case it must have been of insignificantly brief duration. That quality which distinguishes man from the brutes must early, if not immediately, have enlightened him as to the advantages to be derived from the employment of accessory means of attack or defence. By a strange contradiction, the stream of almost Satanic ingenuity which since the time of Adam or of Cain has gone on widening, and deepening, and strengthening—the tide of invention which has brought us the cannon and the rifle, the shell and the torpedo, which has improved the rude guns of the fifteenth or sixteenth centuries into the Armstrong of the present, which has changed Brown Bess into the Martini-Henry, which has developed the "infernal machine" of Fieschi into the mitrailleur of our own day—this stream took its rise in the God-like quality of reason. Man's intelligence at once prompted him to do that which was to the beasts, against whom his earliest wars were made, impossible, viz., to second his efforts by such assistance as he could draw from material resources. To weight the fist with a stone, to add force to the blow by means of a stick or club—such were the expedients at first adopted, and which we know, on the highest of all authorities, were employed in the daybreak of the world's history with fatal success. But, by degrees, that faculty which had suggested these rude auxiliary weapons, reached forward to other developments, and gave us the fashioned side-arm of definite form, the shaped weapon of stone or flint, of wood and bronze, of iron and steel. And then, as the study of the art expanded, it became obvious that a great advantage would result from the adoption of contrivances which would enable the enemy to be struck at a greater distance than hand weapons permitted; and so we get to the class of missile weapons—to the javelin, the assegai, and others, to be thrown by hand, and the projectile weapons, such as the blow-pipe, for projecting poisoned darts, the bow, the cross-bow and the sling, and the more powerful engines of

war, such as the catapult and ballista. And now we strike the track which leads more directly down to our own age. The range of these projectile weapons was so small, and their accuracy was so imperfect, while the importance of range and accuracy became so conclusively established, that the next considerable development naturally took these directions. At this point we mark the introduction of gunpowder, by which the ranges of offensive weapons and their practical importance were at once immensely increased.

With the introduction of fire-arms we mark, indeed, a new epoch, although the object remained the same—the killing or disabling of your enemy at the greatest distance, and with the greatest ease and certainty. The art received a new impulse; the "villainous saltpetre" breathed into it a new life; and since this time men have laboured with an unfailing zest at the perfecting of fire-arms, to the gradual pushing into the background of mere hand or missile weapons. During this period the successive improvements have nearly all taken the form of some advance in the production of long-range arms of precision of increased destructiveness. The greatest distance, the greatest and most irresistible certainty of destruction—these were the two main elements of success, the attempted achievement of which has advanced us from the blunderbuss to Brown Bess, from Brown Bess to the Brunswick rifle, from the Brunswick rifle to the Enfield, from the Enfield to the Henry, and Whitworth, and Metford. With cannon, in the same way, pressed by the same considerations, we have advanced from the rude appliances of the sixteenth and seventeenth centuries to the smooth bores which won the victories of Nelson and of Wellington, and, again, to the rifled guns of Armstrong, and Whitworth, and Woolwich. Again, from the simple round shot of an early age, or the rude and imperfect shell of the seventeenth century, we have travelled forward, always in the direction of increased destructiveness, to the shrapnel, and the segment, and the huge, far-reaching common and double shell, with their enormous charges of powder, and to the Palliser projectiles, which set at defiance the stoutest armour-plating.

But, beyond a point, precision and range lose their practical value. Where exactly that line is to be drawn it is difficult to say. Some enthusiasts would probably place it at the limits of human vision; practical soldiers, however, know that other considerations than these really determine the limits. At all events, when men had got to military rifles, which would shoot with accuracy for half a mile or three-quarters, their instinct instructed them to seek to exercise their ingenuity in another direction. To multiply the rate of fire, within the limits already attained, became the problem of the day, and the result of this movement has been the introduction of breech-loading rifles of immense variety, and many of surprising excellence.

This brief and imperfect outline of the history of the subject will enable us to note the direction in which the tide of improvement has gradually but surely set, and to recognise, in a general way, the objects which the artillerist and the rifleman have endeavoured to attain.

But it is also important to recognise the influence of other considerations besides those of achieving determinate results. War is an art essentially of practice and not of theory; and while theorists have been elaborating complex contrivances for the destruction of human life on the largest possible scale, the soldier, in his blunt way, has been ever at hand to exclaim: "C'est magnifique, mais ce n'est pas la guerre." Simplicity in warlike appliances is a necessity of their existence, which unpractised designers are apt to overlook. Economy, too, is a consideration which the soldier cannot afford to disregard. Capability of resisting rough usage, transport, exposure, and climatic changes may also be classed among the essentials of engines of war, the due observance of which limits the channel along which the military inventor must travel. In the case of warlike stores for English use, these considerations are especially important, on account of the scattered nature of our dependencies, the variety of climates to which the stores are likely to be exposed, and the certainty that, in transport to our distant possessions, they will have much rough treatment to endure. This is a lesson which inventors, unfortunately, are slow to learn. They pursue a phantom of theoretical excellence in utter disregard of the consideration that the soldier wants the real, not the ideal. They trample ruthlessly on the practical arguments which are opposed to their headlong progress, and push impatiently on one side the objections which those who know what war is venture to suggest. Even so distinguished a man as Sir William Armstrong has not steered clear of this rock. It is noticeable that, where his inventions in war *matériel* have trenched upon the province of the artilleryman proper—in his breech-closing arrangement, for example, in his fuses, and his shells—they have all been more or less failures. When only mechanical, as distinguished from practical military considerations, were concerned, as in the structure of his guns, they have been eminently successful. To those readers who may now, or at some future time, conceive the idea of designing some weapon of war, we would give this serious advice: Whatever you may propose, be practical. Seek the advice, if you can, of some plain-spoken soldier; one who has seen service; one who knows something of the hurry and confusion and destruction of action, of the roughness of military transport; who can tell you of the rains and heats of India; who knows how clumsy are a soldier's fingers, and how little suited to ingenious refinements; one who can tell you, too, something of the brilliant failures of scores of clever but unpractical inventions, of fair hopes and extravagant promises wrecked on the first contact with the rough touchstone of practice—one, above all, who will not mince matters, but will say plainly, if need be, "Yours is the silliest and most unpractical invention which I have ever seen." He is the best friend to the inventor who speaks thus; he is the best friend also to his country, for he thus directs the inventive genius of the country into a useful course, instead of allowing it to filter itself away through vain channels into dreamland. On the other hand, we desire fully to recognise that the inventive mechanical genius and resource of England are among her native advantages, as substantial and important as her coal mines—advantages to be fostered and cherished by all means, and to be promoted by a liberal policy of encouragement on the part of both soldiers and the Government.

If the present papers should have the effect of directing attention to war material, and stimulating the ingenuity of some who may honour them with their perusal, they will have accomplished more than the writer can dare to expect. He, on his side, would fail of his duty if he did not, with all emphasis, urge those who would enter upon the difficult and precarious path of improving our war material, to be, above all things, simple and practical. As Frederick the Great said, "What is not simple is not possible in war."

Weapons of war may be conveniently grouped into three main classes* :—

1. PORTABLE ARMS.
2. ARTILLERY.
3. SPECIAL INSTRUMENTS OF WARFARE.

Each of these classes admits of further and almost indefinite subdivision. We will proceed to consider them separately, under their particular heads.

I. PORTABLE ARMS.

Under this head are included all weapons which are borne upon a man's person. They are of two principal divisions :—

(1.) *Side-arms.*

(2.) *Fire-arms.*

(1.) Under the head of side-arms are included swords, spears, lances, daggers, bayonets, pikes, javelins, arrows, and the like. The class is really a more comprehensive one than many persons suppose. The great advances made with fire-arms must be acknowledged to tend to push such weapons as swords and bayonets into a more subordinate position. If you can kill your enemy a mile off, the prospects of his being able to close with you are evidently less than when the range of your weapons was only a few score yards. Similarly, the great increase in the rapidity of fire of modern fire-arms renders less possible a successful charge of cavalry upon an infantry line or square, and by so much reduces the value of the sabre or the lance. But these considerations, which are perfectly just in themselves, have been pushed too far by theorists, and many have hastily and improperly jumped to the conclusion that the days of the bayonet and sword are gone by. To this the experience of the Franco-Prussian war furnished an

* The classes have been placed in the above order because that order is, to some extent, historical, and indicates roughly where the most ancient and most modern contrivances will generally be found.

emphatic contradiction. It is quite clear that despite the improvements in fire-arms, hand-weapons still possess considerable importance—that they may even determine the crisis of a stubborn fight. If an obstinate enemy cannot be dislodged from his entrenchments by a musketry or artillery fire, against which his defences may afford him ample protection, he must be driven out with the bayonet, at whatever cost, and this was actually done more than once in the war already alluded to; while, although cavalry may no longer be employed to ride down infantry squares, they will still be required to sweep over the fields of battle, to complete a disorganisation already commenced, to convert a retreat into a rout, to drive home the wedge which the rifle and cannon have inserted. Here, therefore, we see a continued use for the bayonet, the sword, and the lance; and, accordingly, we find all those weapons retaining their place in the British service.

There are a considerable variety of swords in use in our army—the whole being made at the Royal Small Arms Factory at Enfield. The principal types of swords are those for the cavalry, and the navy cutlass. Of the other ten sorts of swords enumerated in the official vocabulary, the greater part are for serjeants, for Highland regiments, for volunteer non-commissioned officers, etc. Pioneers have a sword with a saw-back, which is found useful in sawing through wood, removing obstacles, and doing some of the special work which pioneers are required to perform. It is noticeable that there is a growing tendency to utilise hand-weapons for more than one purpose. This is perhaps a natural result of the decreased importance of these weapons for the particular purpose to fulfil which they were originally introduced.

We thus find that the latest pattern of bayonet—that which has been proposed for use with the Martini-Henry rifle—is at once a sword, a saw, and a bayonet. This weapon has been favourably reported upon. It serves to saw fire-wood on an emergency; it may be useful for clearing away light obstacles; it gives the infantry soldier what the simple bayonet does not, an efficient hand-weapon for personal defence or attack. This is a more useful combination than that which has been proposed by some inventors—viz., to combine in one a spade or trowel and a bayonet, or to make the bayonet so broad and flat that it could be worn round the neck as a piece of defensive armour for the breast. We have seen specimens of both these weapons, and have recognised in them the handiwork of the unpractical inventor. If the bayonet is to be utilised for more than one purpose, the best combination is undoubtedly that described above—of a sword, a saw, and a bayonet, the handle serving to attach it to the barrel of the rifle.

Some of the best—probably the best—swords in Europe are manufactured at Solingen, in Rhenish Prussia. Not less remarkable than the excellence of these weapons and their fine temper, is their cheapness. An infantry officer's regulation sword, with scabbard complete, can be bought at Solingen for something under £1; an artillery officer's sword for about a guinea. If purchased of good London makers, these weapons cost from £4 to £5; but the London swords, the blades for which are generally obtained from Birmingham, are in no respect better than those made at Solingen.

Visitors to the Paris Exhibition of 1867 will not readily forget the magnificent exhibition of sword cutlery furnished by M. Carl Reinh Kirschbaum, of Solingen, and which, although surpassed in decorative excellence by some of the French makers, whose highly ornamental and costly swords are rather examples of goldsmiths' than of cutlers' work, was unequalled for solid excellence and cheapness by any swords in the Exhibition. The Solingen makers prefer cast steel to damascened blades; the introduction of the iron by which the damascened appearance is produced being considered apt to soften the sword and spoil its high character, which is estimated in a great degree by the just and complete "return" of a blade after bending. All sword-makers are very far from agreed upon this point. By some it is thought that the extent to which a sword will bend is even more important than its perfectly accurate return to straightness after bending.

On this point the following remarks occur in the official report on the "Portable Arms" in the Paris Exhibition:—"The power which a blade may have of straightening again is accepted by the Solingen makers almost as a crucial test of its excellence; and when a sword is bent to a point beyond which it can return perfectly straight, they would almost prefer it to break than that it should exhibit softness and remain crooked. On the other hand, it is argued by some that, although it is well that a sword should straighten, it is better that it should remain permanently bent than that it should break, a bent sword being more serviceable than a broken one; and the Solingen makers are considered to lay undue stress upon the straightening qualities of the sword. As, however, the flexibility of a blade depends, after its quality, upon its transverse section, and as Solingen exhibits swords which will bend almost round a man's body, it would seem as though all the flexibility that could possibly be desired can be obtained without any admixture of iron. When a Solingen maker says he prefers that his sword —if it be bent beyond what it is capable of standing—should break rather than remain crooked, the burden of proof rests upon others of showing what useful purpose would be served by making a blade capable of bending further at the expense of some softness."

Next to the sword and the bayonet—weapons which we have seen are coming, in the hand of the infantry soldier, to be combined—the lance is the most important of military hand-weapons. Skilfully used, the lance is a most formidable weapon; unskilfully used, it becomes a terrible encumbrance. In India the lance is largely employed. It is peculiarly useful in pursuits or in isolated combats. A few years ago, the bamboo staff was adopted for the lance of the British soldier, as being lighter than ash. Of the head of the lance there is not much to be said, except that it should be made of a good quality of steel, and of a form favourable to inflicting a serious wound. In the British service, the triangular head is preferred to the simple conical point.

It is unnecessary, we think, to dwell at any greater length upon the subject of weapons of the sword and lance class; nor is it worth while to touch upon the assegais of Africa, the arrows of the Indian, or the javelins and spears still in vogue among some of the ruder nations. The consideration of these weapons can have no practical value. They are interesting rather from an antiquarian point of view, and as so many examples of the ingenuity of man in producing a large variety of means of attack and defence. The projectile weapons—such as the javelin, the djerid, and the arrow—have completely lost their importance now that fire-arms have reached so high a pitch of development, and can be procured even by the poorest and most savage nations. Even hand-arms proper, such as swords, lances, and bayonets, have faded into a subordinate and wholly secondary position, although, for special purposes, they must ever retain a certain value. But we must hasten on to the more interesting branch of our subject, and to the consideration of fire-arms, about which we shall have much to say.

PROJECTION.—I.

INTRODUCTION.

In the Lessons in Plane Geometry given in the Popular Educator, the figures treated of are such as possess *length* and *breadth* only, these figures being considered as traced upon a flat surface, called a *plane*, thus showing their exact forms as they are really known to be.

In these papers we shall treat of the delineation of *Solids* —that is, bodies which possess not only length and breadth, but *thickness* as well; and the science by which lines are so disposed that the representation of the object may seem to stand out, or *project*, from the flat surface of the paper, is called *Projection*, which is a branch of Solid or Descriptive Geometry.

The subject may be divided into—

Orthographic Projection, by means of which objects are projected by parallel lines from given plans, elevations, or other data, the object being placed in any given position.

Isometrical Projection*, by means of which a view of an object is projected at one definite angle, a uniform scale, proportionate to the real measurement, being retained throughout.

Perspective, by which objects are drawn as they *appear* to the eye of the spectator from any point of view that may be selected.

* From two Greek words, meaning equal measures.

The present course of lessons will embrace the whole of these divisions; combining also the mode of obtaining required sections, the methods of describing the peculiar curves generated by one solid body intersecting or *penetrating* another, and the development of surfaces—that is, the construction of the exact shape to which a metal plate or other material is to be cut, so as to form or cover the required object in the most ready and accurate manner, and with the least waste—a branch which will be further considered in subsequent studies, devoted to the technical drawing adapted to the requirements of the metal plate-worker, boiler-maker, and tinman. The lessons are given in as simple a manner as possible, so that the student may be able to follow them with interest, and may be led to desire still further instruction than is here afforded; and it is hoped that the pleasure and benefit he receives from knowledge may awaken in him that spirit of enthusiasm which is the mainspring of all progress. It has been from the *want* of enthusiasm that our workmen have been content with the small amount of knowledge which they have obtained from their "mates" in the shop. It has been this apathy which has caused so many to be satisfied with the "rule of thumb" instead of the rule of *science*. It is not the province of these lessons to dilate on the natural history of enthusiasm; but our object is to warm up the spirit of our fellow-countrymen—to convince them that, if they will but study the principles of the sciences on which their trades are based, they will, with their acknowledged *manual* superiority, hold their own against the men of every country in the world. Let us, therefore, interpret *interest* in their occupation to imply *enthusiasm;* and let us translate enthusiasm to mean *that spirit which urges every man to do his work as well as it can possibly be done,* and to develop the mental powers with which his Creator has endowed him to their fullest extent, so that when he leaves the workshop of life he may, in the words of Longfellow, leave "footprints in the sands of time."

ELEMENTARY PRINCIPLES OF PROJECTION.

Fig. 1.—If we place two planes or surfaces at right angles to each other, so as to form a floor and a wall, the floor, A B, is called the horizontal, and the wall, C D, the vertical, planes of projection.

THE PROJECTION OF LINES.

No. 1.—Let us take a piece of wire, and fix it in an upright position, *a b*, then the point on which the wire rests is called the horizontal projection, or *plan;* and if we carry lines directly back from its extremities until they cut the vertical plane in *c* and *d*, the line *c d* is the vertical projection or *elevation* of the wire.

No. 2.—If a wire, *e f*, be fixed at right angles to the vertical plane, the point *f*, in which it is fixed, is the *elevation*, being the view which would be obtained if the model were placed on an exact level with the eye, the point *e* being immediately opposite the spectator, so that the end only of the wire could be seen. If now perpendiculars are dropped from *e* and *f* until they meet the horizontal plane in *g* and *h*, the line uniting *g* and *h* will be the *plan* of the wire, or the view obtained by looking straight down on it. It must be remembered that in projection the visual rays are supposed to be *parallel* to each other, and not *convergent*,* as in pictorial perspective.

Further, if we suppose a wire, *i j*, to be suspended in space, perpendiculars dropped from its extremities to cut the horizontal plane will give the *plan k l;* then, if lines be drawn from *k* and *l* to meet the vertical plane in *m* and *n*, and perpendiculars be raised from these points, intersected by lines drawn from the ends of the wire parallel to *k m* and *l n*, the points *o* and *p* will be obtained, and the line joining these will be the *elevation* of the wire *i j*.

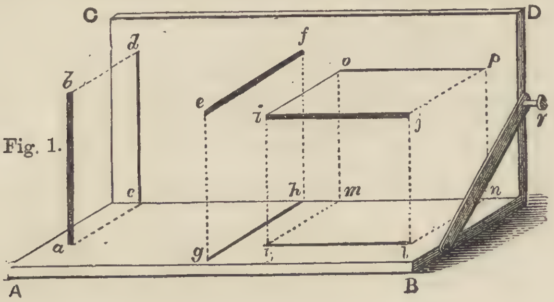


Fig. 1.

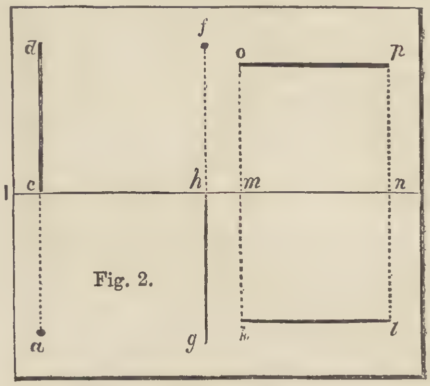


Fig. 2.

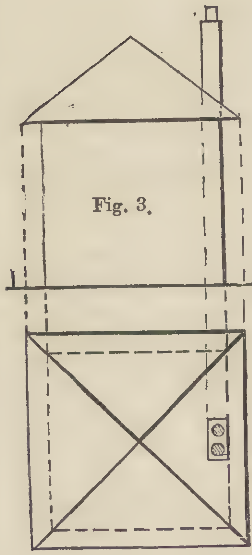


Fig. 3.

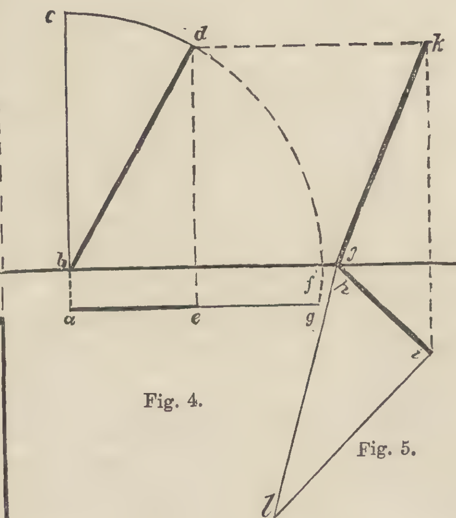


Fig. 4.

Fig. 5.

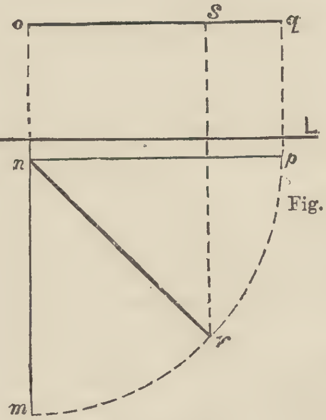


Fig. 6.

* *Convergent.* From con, *with*, and vergo, *to incline* (Latin). Arising in various points, and approaching each other until they meet.

In the model used for illustrating this lesson, the vertical and horizontal planes are connected by hinges, and are kept at right angles to each other by means of a brass loop. If now the wires be removed, and the pin, r, be withdrawn, so as to allow the plane, C D, to fall backwards, the two planes of projection will form one surface, separated only by the line I L (Fig. 2), and the plans and elevations will be seen in the positions in which they are placed in projection.

The line separating the two planes is called the *intersecting line*, and will be lettered I L throughout these lessons.

It must be borne in mind that the *plan* of an object does not mean merely the piece of ground *it stands* upon, but the space it overhangs as well: thus, the piece of ground on which the small lodge (Fig. 3) would stand, is represented by the dotted square in the plan, whilst the true space which the building covers or overhangs is represented by the outer square.

It will be seen that in all the figures hitherto shown the lengths of the plans and the heights of the elevations are the same as the heights and lengths of the objects they represent; thus $c\,d$ is the same length as $a\,b$, and $k\,l$ and $o\,p$ are the same length as $i\,j$; but plans are not always the size, nor are elevations always the full height, of the object, both being dependent on the position or angle in which the subject to be drawn is placed. Before proceeding to treat of the changes which lines undergo by alteration of position, it is necessary that the terms used to define such positions should be understood, and for this purpose we again refer to Figs. 1 and 2.

Here we have the line $a\,b$ standing upright on the floor of the model, and as its distance from the wall is the same throughout its entire length, it is said to be *at right angles (or perpendicular) to the horizontal, and parallel to the vertical plane.* The line $e\,f$ is said to be at *right angles to the vertical, and parallel to the horizontal plane;* and it is evident that the line $i\,j$ is *parallel to both planes.*

It will be seen that whilst the plan of a line when standing upright is a mere point (Fig. 2, a), the plan of the same line when placed horizontally, as $k\,l$, is the full length of the original. Figs. 7, 8, 9, and 10 will account for this difference, and will show how the length of the plan is dependent on the angle at which the line is inclined.

Let the original position of a wire (Fig. 4) be perfectly upright, then its plan will be the point a, and its elevation the line $b\,c$.

Now, if this wire be made to work on a hinge-joint at b, and if the end c be moved from left to right, as from c to d, the end d being kept the same distance from the wall of the model, the wire will still be *parallel* to the vertical, but *inclined* to the *horizontal* plane (of course it may be inclined at any angle; in this case it is at 60°).

To find the plan of this wire, draw a line from a, parallel to I L. From d drop a perpendicular to cut this line; then $a\,e$ is the plan of $b\,d$ in the position in which it is now placed (viz., parallel to the vertical, and inclined at 60° to the horizontal plane); and if the movement of the wire were continued until it reached f (it would then be parallel to both planes), the plan would be the same line extended to g.

The line $b\,d$ is said to be placed at a simple angle, because it is inclined to *one* plane, but remains parallel to the other. Let us now suppose the wire fixed in this slanting position, as far as its inclination to the horizontal plane is concerned—but if the whole hinge is made to rotate on a pivot, so that, without altering the slant, the end d may be turned forward—the line will then be at a *compound* angle, that is, it will be inclined, or slanting, to *both* planes.

Now it will be remembered, that although we have turned the wire round, we have not altered its slant to the horizontal plane; it will therefore overhang a piece of ground of exactly the same shape and size as it did in Fig. 4; but the position of that space will be changed. Let us now assume that, in addition to the wire being inclined at 60° to the horizontal, it is required to slant at 45° to the vertical plane. Place the plan, $h\,i$ (Fig. 5), at 45° to the intersecting line, and draw perpendiculars from its extremities; the line from h will cut the intersecting line in j, and will give the base of the line. To find its height, we must remember that, although we turned the wire round, we did not alter its slant, and therefore the height of the end d remains the same as it was; so that an horizontal line being drawn from d (Fig. 4), to meet the perpendicular drawn from i in the point k, the line $j\,k$ will be the *projection* of the wire inclined to both planes at the required angles.

It will be seen that in this case both plan and elevation are shorter than the line itself.

EXERCISE.—To find the real length of a line when it is inclined to both planes, and its plan, $h\,i$, and the height of the end is given. Draw a line, $i\,l$, at right angles to $h\,i$, and make it equal to the given height. *Then the line $h\,l$ will be the real length;* for the plan, the original line, and a perpendicular dropped from its end form a right-angled triangle; and this triangle, instead of standing upright, as in Fig. 4, is placed horizontally in Fig. 5; and the line $h\,l$ will thus be found to be of the same length as $b\,d$. This may be illustrated by holding a set-square vertically, and rotating it on its edge until it lies on the horizontal plane; the real length of the long edge (or hypothenuse), which when the set-square was vertical was represented by its plan, $h\,i$, will then become visible.

Fig. 6.—Again, it has been shown that if a wire were fixed at o, at right angles to the vertical and parallel to the horizontal plane, its plan would be $m\,n$, and its elevation the point o; and if it were rotated on the point n until it became parallel to I L, its plan would be $n\,p$, and its elevation $o\,q$;

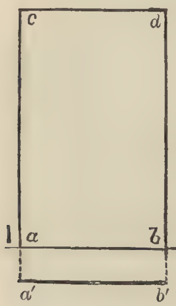


Fig. 7.

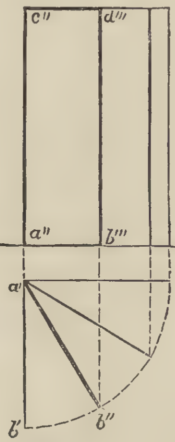


Fig. 8.

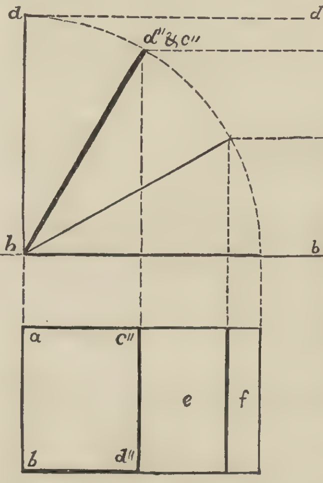


Fig. 9.

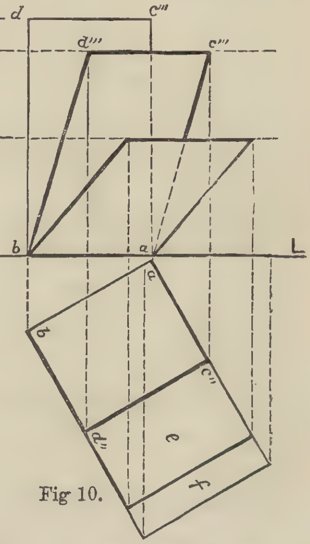


Fig 10.

but, on the principle shown in Figs. 4 and 5, it will be evident that if the wire be rotated only as far as *r*, the elevation of it will be the line *o s*.

PROJECTION OF PLANES OR SURFACES.

The same laws which guide the projection of single lines will also govern the delineation of planes, which are flat surfaces bounded by lines. Let *a b c d* (Fig. 7) be a metal plate, the surface of which is parallel to the vertical and perpendicular to the horizontal plane: its *plan* will then be the line *a′ b′*. If now this plane be turned, so as to be at right angles to both planes, its plan—that is, the line on which it would stand—will be *a′ b′* (Fig. 8), and its elevation the line *a″ c″*, or the view obtained when looking straight at the long edge.

Now let this plane rotate on the line *a″ c″*, as a door on its hinges, until the plan reaches *b″*, then a perpendicular drawn from *b′* will give the rectangle *a″ c″ b‴ d‴*, which will be the projection of the plane, when perpendicular to the horizontal and inclined to the vertical plane, the height remaining unaltered. The other rectangles show the projections of the plane when further rotated.

Fig. 9.—In this figure the plane again rests on *a b*, its edge, *b d*, only being visible in the elevation; but this edge hides the opposite one, which is parallel to it, and therefore the points *a* and *c″* are immediately at the back of, or "beyond," *b d*. Let us now rotate the plane on *a b*, as in closing a box-lid or trap-door, then the plan of the plane will be the rectangle *a b c″ d″*; and the more the plane is lowered, the longer the plan will become, as is shown at *e* and *f*. Notwithstanding the slanting direction which the plane has assumed in relation to the horizontal plane, it still remains at right angles to the vertical plane. This is shown in the plan, where the lines *a b* and *c″ d″*, which represent the upper and lower edge of the plane, are perpendicular to I L. Let us now place the plane at a compound angle; this will be done by rotating the plan (*carefully lettered*, as in Fig. 9); then, perpendiculars drawn from each of the points, intersected by horizontal lines from the corresponding points in the elevation, will give the required projection. The process is so plainly shown in the illustration (Fig. 10) that it is believed further explanation will be unnecessary.

The student is urgently recommended not to be content with simple copying the diagrams herein given, which are merely to be considered as illustrations of principles; and thus, unless those principles be understood and applied, nothing will be gained. He is therefore advised to vary the form of the plane, and to project it at various angles.

MINERAL COMMERCIAL PRODUCTS.—I.

INTRODUCTION—MINERAL RAW PRODUCE.

WHILE we are indebted to the animal and vegetable worlds for a vast variety of useful products used for food, clothing, medicine, the constructive arts, and a countless number of other purposes, it is from the mineral kingdom that we obtain our coal, iron, building stone, precious metals, salt, etc. Of the uses of these and other mineral commercial products named in the annexed table, it is our purpose to give some account in this and subsequent lessons in this important subject. Mineral raw produce may be conveniently divided and considered as follows :—

I. METALS AND METALLIFEROUS MINERALS.

Iron: *Magnetic iron ore, titaniferous iron ore, red hæmatite, brown hæmatite, spathic ores, clay ironstones, other ores. Process of smelting, puddling, etc.; steel, supply of iron.* Gold, silver, quicksilver, platinum, tin, copper, lead, zinc, aluminum, antimony, bismuth, cobalt, arsenic, manganese, chromium (*with their chief ores, uses, localities*, etc.).

II. EARTHY MINERALS.

(*a*) *Coals and allied Substances.*

Coal: *Lignite, bituminous coal, steam coal, anthracite. Supply of coal.* Jet, amber, *naphtha, petroleum*, asphalt, mineral pitch.

(*b*) *Limestones, Limes, and Cements.*

Common limestones, ornamental limestones, and so-called marbles; marble, coral limestone, marl, calcareous sand, gypsum; *composition of limes, stuccoes, and cements.*

(*c*) *Siliceous and Felspathic Substances.*

Rock crystal, quartz, and flint; sandstones, paving, mill, and building stones; siliceous sands, rottenstone, Bath bricks, Tripoli powder, Bilin powder, berg-mehl, tellurine.

(*d*) *Igneous and Metamorphic Rocks.*

Granites: *Syenite*, mica, talc, asbestos, serpentine, basaltic rocks; *greenstone, whinstone, trap*, lava, obsidian, pumice-stone, pozzuolano, and trass.

(*e*) *Clays and allied Substances.*

Common clay, yellow, brown, and blue; kaolin and petuntse, pipe clay, fire clays, *Stourbridge clay*, fuller's earth, red and yellow ochres, slates, hone stones.

(*f*) *Earths of Sodium, Potassium, Boron, Sulphur*, etc.

Common salt, rock salt, soda, *chlorine*, alum, natron, borax, saltpetre or nitre, cubic nitre, heavy spar, celestine, strontianite, fluor spar, sulphur, *sulphuric acid*, graphite or plumbago; mineral manures, *phosphates of lime.*

(*g*) *Precious Stones.*

1. Carbonaceous: diamond.
2. Aluminous: ruby, sapphire, emerald, topaz, corundum, garnet, beryl.
3. Siliceous: amethyst, Cairngorm stone, agate, sardonyx, opal, chalcedony, carnelian, jasper, lapis-lazuli, turquoise.

1.—METALS.

IRON.

This valuable and indispensable metal is, in a variety of forms, almost universally diffused throughout the earth. It is of incalculable use in all the appliances of modern civilisation —in machinery of every description, instruments, implements, and tools of all kinds; architecture and domestic fittings and utensils; conveyance, both inland and maritime; apparatus for warming, lighting, and water supply; and even in medicine, to impart renewed vigour to the failing human frame. It occurs in all parts of the earth, in all geological formations, to which it contributes a great part of their colouring matter; it is found in all spring and river waters; and it enters into the composition of both plants and animals. It is present, too, as the principal ingredient, in the extraordinary fragments called meteoric stones, and is thus a constituent of worlds beyond our own. It can be melted and cast into moulds, softened, and hammered out into plates, drawn out into bars and wires, tempered to almost any degree of flexibility, hardened so as to scratch glass, and sharpened to the keenest cutting edge. In some of its natural forms, and also when heated to redness, iron is highly magnetic. Pure iron is white, or greyish-white, lustrous, soft, and tough, and it is one of the most infusible of metals (fusible at 3,480° Fahr.). Its specific gravity is 7·84. When beaten out it appears granular in structure; when drawn, fibrous; and to this latter peculiarity is attributed its extraordinary tenacity.

Metallic iron as it occurs in meteoric stones is usually alloyed with nickel and other metals, but its occurrence as terrestrial native iron is doubtful. There are many minerals containing iron, but of these only the oxides and carbonates are so used by the smelter; they are magnetic iron or loadstone, specular and micaceous iron ores, the red and brown hæmatites, the spathose ore and the clay ironstones.

The maximum development of iron ores appears to be in the palæozoic rocks, the largest and richest deposits being contained in the Laurentian rocks of North America and Scandinavia; they are abundant in the Devonian rocks of Germany and south-west of England. The Carboniferous system is especially marked by the presence of interstratified argillaceous carbonates, both in America and Europe. The celebrated kidney ore of Cumberland is found in Permian strata, the Secondary rocks are rich in bedded deposits of ironstone, and the Tertiary series yields limonites.

Magnetic iron ore, or *Magnetite*, is the black oxide (Fe_3O_4, or $FeO + Fe_2O_3$), and contains 72·41 per cent. of iron. It occurs in many parts of the earth in huge masses, forming the substance of hills and even mountains, as in the mountain of Blagod, among the Urals, and in some hills of Swedish Lapland, Mexico, and Styria. In Canada magnetite is found abundantly in the gneiss and crystalline limestones constituting the Laurentian rocks; it occurs in irregular beds, often of considerable thickness, in one instance as much as 200 feet. In the State of New York this mineral occupies the Valley of Adirondac and

its neighbourhood for a mile in width and twenty miles in length. In our own country it occurs in Dartmoor, at Rosedale, and in Antrim; and it is found also in New Jersey, Pennsylvania, Nova Scotia, and parts of the East Indies. This ore is not only the richest in pure metal, but furnishes also the finest qualities. It is remarkable, however, that some veins, without any apparent chemical difference, produce finer iron than others. The produce of the mines of Dannemora in Sweden is of the finest description, and is employed in the production of the highest class of steel. Magnetic iron ore occurs chiefly in veins and fissures in diorites or dolerites, or in interstratified masses in metamorphic rocks.

Titaniferous iron ore contains proto- and per-oxide of iron, titanic acid (an oxygen compound of the metal titanium), and magnesia in variable proportions. The bar iron or steel made from titaniferous iron ore possesses unusual strength and a peculiar mottled appearance. This ore is chiefly employed with others to impart a high degree of toughness to the metal produced.

Red hæmatite is a sesquioxide of iron (Fe_2O_3), with 70 per cent. of iron. It is distinguished from the less rich brown hæmatite by its red streak, that of the latter mineral being brown in colour. Red hæmatite is known by special names, according to its different varieties :—

Specular iron ore, oligiste, or *iron glance*, is brilliant, hard, and distinctly crystallised. It is found in Elba, Brazil, etc.

Micaceous iron ore is scaly, crystalline, loosely coherent, and similar to graphite in structure. It is met with in South Devon.

Kidney ore is a hard botryoidal variety, devoid of lustre, such as that of Cumberland.

Red ochre is a compact, earthy, and more or less clayey variety, and is usually employed in the preparation of red and yellow ochres and umbers.

Red hæmatite occurs abundantly in England and Wales, and, being rich, is much used for mixing with the poorer ores of the coal formations in the process of smelting. The red ore is worked in Cumberland, at Ulverstone, in the Forest of Dean, Cornwall, North Wales, Ireland, Belgium, Nova Scotia, Elba, Sweden, Missouri, and the neighbourhood of Lake Superior.

Brown iron ore or *hæmatite* consists essentially of three equivalents of water united to two of peroxide of iron, or $2Fe_2O_3 + 3H_2O$, and is compact and earthy.

Gothite is another hydrated oxide ($Fe_2O_3 + H_2O$), but it is crystallised. Both minerals are usually included in the smelter's term "brown hæmatite," and, though resembling the red in outward appearance, are distinguished by their brown streak. Bog-iron ores, and those deposited in the beds of lakes by the action of infusorial life, belong to this group of iron ores.

Brown hæmatites are largely worked in the Carboniferous rocks of England and South Wales; in the Lias of Oxfordshire, Northamptonshire, and Yorkshire; in the Lower Greensand near Devizes, and in Buckinghamshire; in Oolitic strata in France, Bavaria, Wurtemburg, Luxemburg, etc.; and in the Wealden rocks of the Boulonnais. Bog-iron ore is abundantly developed in North Germany, Sweden, Norway, Finland, and Canada.

Siderite, spathose iron, or *brown spar*, is a carbonate of the protoxide of iron (FeO,CO_2), or, commonly speaking, carbonate of iron. The spathic ores are sparry or crystalline, and are associated with varying quantities of carbonate of lime and of magnesia. Spathic ore, when pure, is white; but it becomes reddish on exposure to the air. It is particularly abundant in Styria, where the mountain Erzberg, near Eisenerz, is capped by the mineral to a thickness varying from 200 to 600 feet; in Carinthia and other parts of Austria; at Siegen, in the Stahlberg, or "steel mountain" (Rhenish Prussia); and in the United States (New York and Ohio). The principal English deposits are those of Weardale, in Durham; Exmoor, Devonshire; and Brendon Hill, in Somersetshire.

Clay ironstone is an amorphous argillaceous carbonate of iron, mixed with small quantities of lime and magnesia, and sometimes, as in the "black band," with bituminous matters. The poorest of the serviceable ores, they are, nevertheless, in Britain, the most important, furnishing nearly two-thirds of the total yield of iron. Being mostly connected with the Coal formations, they are cheaply worked, having in immediate proximity a plentiful supply of fuel and limestone for their reduction. There are many varieties—that called the "black band" being among the most valuable, from the ease and cheapness with which the ore may be calcined, by burning it in heaps without any additional fuel.

The ores are extensively worked in South Wales, Monmouthshire, Shropshire, Staffordshire, Yorkshire, Derbyshire, Lanarkshire, Stirlingshire, County Antrim; in Belgium, Silesia, United States, North China, Japan, India, Brazil, and Tasmania. Ireland has large deposits, which are not much worked. Clay ironstones are not confined to the Carboniferous rocks, but are extensively met with in the Lias, Oolite, and Wealden, and even among Tertiary rocks. Of this character are the rich iron district of Cleveland, in Yorkshire, and similar deposits in France.

TECHNICAL DRAWING.—I.

INTRODUCTION.

THE practice of Drawing is of such paramount importance in the mechanical arts, that in addition to the scientific principles given under the titles of Practical Geometry, Projection, Perspective, Building Construction, etc., a chapter devoted specially to Drawing applied to various trades will now be given in each weekly number of the TECHNICAL EDUCATOR. In these lessons the various methods of delineation of brickwork, timber constructions, masonry, mechanism, screws, teeth of wheels, etc. etc., will be given; the principles of construction and their application being in every case fully described.

The course of lessons will be so arranged as to combine Linear and Freehand Drawing, whilst Object and Model Drawing will be combined with Perspective and Projection in another set of lessons, the first of which appears simultaneously with this.

Each of these branches will be again divided and sub-divided, and thus, in Linear Drawing, foundations, piles, coffer-dams, wooden bridges, roofs, staircases, doors, gates, machines of various kinds, and steam-engines, with all their details enlarged, will form the subjects of lessons. Alternately with these will be given drawings of masons' and bricklayers' work, etc. etc. Mouldings, borders, scrolls, etc., the forms of tools, etc., form portions of the Freehand section; whilst practical instruction in the uses of mathematical instruments, and in the method of colouring drawings, will complete the course, which it is hoped will be found practically useful to the artisan, whatever may be his particular branch of industry.

Some description of mathematical instruments has already appeared in an early volume of the POPULAR EDUCATOR. It is therefore intended here to give instruction in the practical use of them. It must be understood, however, that it is only by *constant practice* that the power over the instruments is acquired; and the student is therefore urged to rule lines of various thicknesses, to describe articles of different sizes, and to repeat the most elementary figures, first in pencil and then in Indian ink, so as to achieve that manual dexterity and refinement which are so necessary for the mechanical draughtsman.

Let your paper be rather smaller than your drawing-board, so that the edges may not project.

To fasten the paper down, wet the back, and then paste the edges to the board; let it lie flat whilst drying. This is only necessary when the drawing is likely to be some time in hand; for exercises such as are contained in this volume, it will be sufficient to fasten the paper down by means of *drawing-pins*, which may be bought at one halfpenny each.

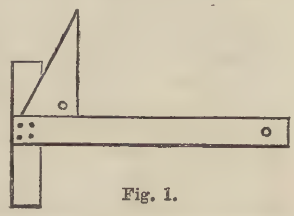


Fig. 1.

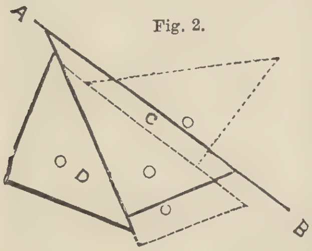
The best T-squares are those where the blade is screwed *over* the butt-end, as in the illustration (Fig. 1), as this allows of the "set-square" (or triangle) passing freely along; whilst, when the blade is mortised into the butt-end, the set-square is stopped when it comes against the projecting edge.

The T-square is to be worked against the left-hand edge of the drawing-board, and should be used for horizontal lines only —perpendiculars are best drawn by working the set-square, as above, against the T-square; for if the T-square be used for perpendicular as well as horizontal lines, the slightest inaccu-

racy in the truth of the edges of the board would prevent the lines being at right angles to each other.

There is in some cases of mathematical instruments an implement called a "parallel rule," made of two flat pieces of ebony or ivory, connected by two bars of brass. The student is not advised to use this in obtaining parallel lines, as, unless the instrument be in very good order, and very carefully used, the lines drawn will not be parallel. The best way to draw lines parallel to each other is by means of two set-squares.* Thus, let it be required to draw several lines parallel to A B (Fig. 2). Place the edge of one of your set-squares, C, against the line, and place the other set-square, D, against the first; hold D firmly down, and move C along the edge of D, and thus any number of parallel lines may be drawn; and if lines at right angles to the parallels are required, it is only necessary to hold C, and place D on it, as shown in the dotted portion of the figure.

Fig. 2.



In inking the drawings, use Indian ink, not writing ink, which rusts the steel of the instruments, and so destroys their refinement. Indian ink may be obtained from twopence the stick. If you intend inking the drawings, you must work the original pencilling very lightly.

From the very onset aim at refinement, neatness, and *absolute accuracy*. Do not be satisfied if your work is *nearly* right. Try again, and, if necessary, *again;* and, with increased care and perseverance, success will be the certain result.

HOW TO USE MATHEMATICAL INSTRUMENTS.

The most important instrument is the compass. A complete pair of compasses consists of the body of the instrument and three movable parts—viz., the steel, the pencil, and the inking-legs, which are fixed in their places either by a screw, or by the end of the leg fitting accurately into a socket in the end of the shorter leg of the compass, and kept in its place by a projecting ledge, which runs in a slit in the upper side of the socket. This is by far the better method, and is used in nearly all modern instruments; its advantages over the screw form are, first, that the movable leg only remains firm in its place as long as the thread of the screw is in good order, but the very force used to tighten the pressure wears the thread away, and then the leg shakes. The consequence of this can be very well imagined, when we remember that one of the leading purposes of compasses is to draw circles, for unless the leg be absolutely firm the circle will not be true, and the point of the pencil or inking-leg will not meet the starting-point, and so an ugly break will be caused; and, secondly, that the screw, being but small, is very liable to be lost.

Be careful that in drawing the movable legs out you do not wrench or bend them from side to side, with the view of getting them out more easily, for by that means you will widen the socket, and cause the instrument to work inaccurately: the proper way is to draw the leg *straight* out.

The steel point is used when distances are to be accurately measured or divided, and therefore compasses which have both points of steel are called "dividers." A pair of these is found in most cases of instruments.

The pencil-leg is used for drawing arcs, circles, etc. Be careful that you keep it exactly the same length as the steel one; this is accomplished by drawing the pencil out a little after each sharpening. In very old-fashioned instruments the pencil is held in a split tube, which is tightened around it by means of a sliding ring; but in those of modern make a short split tube is placed at the end of a solid leg, and the cheeks of this "cannon-leg" are tightened by a screw. This is by far the better construction, as by its means the pencil is not only more firmly held, but the points of the compass may be brought more closely together than in the older form.

The use of the inking-leg (as its name implies) is to repeat the pencil-work in ink; the ink must be *Indian* ink, as already mentioned, and it is advisable to mix a small quantity of indigo with it, as otherwise it has a tendency to turn brown. When you mix the Indian ink, do not rub it very hard, as by that means you roughen the edges, and break off small pieces—they may be small indeed (and do we not frequently find failures caused by very trifling obstacles?), but they work between the nibs of the pen, and cause roughnesses and irregularities of thickness which materially damage a drawing.

On examining the inking-leg, you will find a joint in it. The purpose of this is to enable you to bend the leg at that point, so that the part which contains the ink may be kept perpendicular to the surface of the paper whilst describing a circle, for if the inking-leg were kept straight as the steel one, when the compass is opened to any extent, only *one* of the nibs (the inner one) will touch the paper, and thus the outer edge of the circle drawn will be ragged and rough. In drawing circles, be careful to lean as lightly as possible on the steel point, so that your centre may not be pricked through the paper, for then, as each concentric circle is drawn, the hole will become larger, until all chance of following the exact curve will be lost, and when you come to ink the drawing you will find the difficulty still further increased. "Horn centres" are sometimes used. These are small circular pieces of horn with three needle-points fixed in them; one of these may be placed over the centre on the paper, and pressed down; the horn being transparent, the centre-point will be visible through the small plate, and the steel point of the compass may be placed exactly over it. This is all very well in large drawings, and where the circles to be drawn are at some distance from the centre; but where numerous small circles, immediately surrounding the centre, are required, as in the projections of the sections of cones, the horn plate is useless, as it will cover some of the space on which circles are to be drawn; and further, the point resting on it is raised above the surface on which the other is working, and in small circles this will be a disadvantage. The student is therefore reminded of the old adage, "Prevention is better than cure," and he is assured that if from the outset he endeavours to *lean* lightly on the instrument, practice will soon place him beyond the necessity for the aid of the horn centre. The following hints will be found useful:—

1. See that the steel point of your compass is *round*, and not triangular, which latter form opens the little hole far more than the point would if it were round.

2. See that this point is not *too* thin; it should be rather a blunt point than otherwise, only just sharp enough to prevent it slipping away from the centre.

Should either of these two faults exist, they may be easily remedied by drawing the point a few times over an oil-stone, remembering to keep turning it round whilst moving it along.

3. Hold the compass loosely between the *thumb* and *forefinger* only, allowing the instrument to rest with equal weight on both points, and merely using the finger and thumb to support and guide it.

When a circle is required of a larger radius than can be reached with the compass in its usual form, a "lengthening-bar" is used. This is an extra brass rod, which fits into the socket in the leg of the compass, and has at its other end a socket into which the end of the pencil or inking-leg fits. This forms a pair of compasses with one leg very much longer than the other, and which is, therefore, rather awkward to manage. Here again the student is reminded that the pencil-leg and inking-pen must be bent at the joint, so that they may be perpendicular to the surface of the paper.

The full-sized compass is, however, not well adapted for drawing small circles, and therefore a complete case of instruments contains the bow-pencil and the bow-pen. These are simply small pairs of compasses, the first of which has a pencil and the other an inking-leg. These will be found very useful, and may be purchased separately if not in the case.

For still smaller purposes, "spring-bows" are used. These constitute in themselves a small set consisting of dividers, pencil, and inking-bows. The legs, instead of being united by a hinge-joint, are made in one piece, so as to form a spring, which by its action tends to force the points apart; they are then acted upon by a nut, which, screwing upon a bar fixed in one leg and passing through the other, closes the legs in the most minute degree possible. These will be found of immense

* Get two set-squares (about sixpence each), the one having angles of 45°, 45°, and 90°, and the other 30°, 60°, 90°.

service in the higher branches of mechanical and architectural drawing, where very small arcs and circles are required, as in the delineation of the teeth of wheels, mouldings, and other architectural details.

Another important instrument is the drawing-pen, which is something like the inking-leg of the compasses already described; it is, however, generally smaller in its nibs, and is fitted on to an ivory or ebony handle. The ink should be placed between the nibs by means of a camel's-hair brush. The pen should be held *nearly upright*, with its flatter side next to the rule, the end of the middle finger resting on the head of the screw. Before you ink any line of your drawing, be careful to try your pen on another piece of paper, in order that you may ascertain whether the line drawn by the pen would be of the proper thickness, and if not the pen may be adjusted by means of the screw, which acts in a way similar to the screw on the spring-bows already described. Before putting your inking-leg or drawing-pen away, be sure to wipe it well, and finally to pass a piece of paper between the nibs, so as to remove any ink that may have dried, or any grit which may have been deposited.

The rule, or straight-edge, which you use when inking your lines, must have a bevelled edge; and further, the bevel must be turned *downwards towards the paper*. This will avoid any smearing which might occur if the edge of the rule were to touch the paper whilst the line is wet.

Scales of different sorts are used in mechanical and architectural drawing; but as the subject of the present lesson does not necessarily involve working "to scale," the uses and construction of these will be found appended to the lessons on the above-named sections of scientific drawing.

The protractor, used in measuring and constructing angles, is described, and its uses explained, in the lessons in Practical Geometry (POPULAR EDUCATOR, Vol. I., page 113); repetition here is therefore unnecessary, and we proceed to mention what are called "French curves" (Fig. 3). These are rules cut into an almost endless variety of shapes, one of which is here shown: they are used in inking curves. To do this, you must turn your French curve about, until some part of it corresponds with the form already drawn in pencil, which may then be repeated in ink, the pen being guided by the French curve. If you cannot find any portion of your rule which will correspond with the whole of your pencilled curve, draw as much of it as you can, and then find the remainder at some other part of your French curve, or on another one. As these useful implements may be had in innumerable patterns, at a very moderate price, the student is advised to provide himself with two or three of them; but the writer wishes it to be plainly understood that he does not imply that by means of French curves freehand drawing may be dispensed with. On the contrary, he urges this practice on all students; for there is such variety of form in drawing, that no mechanical means can possibly supersede the necessity for the accurate and refined education of the eye which is obtained by that study; and further, a little practice will enable students to draw many curves by hand in less time than it would take them to find their places on the French curve.

Fig. 3.

AGRICULTURAL CHEMISTRY.—I.

BY CHARLES A. CAMERON, M.D., PH.D.,

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CHAPTER I.—ON THE ELEMENTARY CONSTITUENTS OF PLANTS.

DURING recent years Agricultural Chemistry, like most of the other branches of experimental science, has made great and permanent progress. Not many years since it was regarded as a mere philosophical pursuit, which, however interesting the abstract truths revealed by it might be, afforded no useful information for the benefit of the practical farmer. Less than a quarter of a century ago, that distinguished agriculturist, Mr. Pusey, stated that husbandry was only indebted to Chemistry for a receipt for making bone manure and a suggestion to utilise flax-steepings as a fertilising agent. However unfounded such assertions may have been twenty-five years ago, it is now generally conceded that Chemistry has conferred the most important and lasting benefits upon agriculture. It has thoroughly investigated the composition of plants; it has shed a flood of light upon those wonderful processes by which the vegetable mechanism organises into the most complex substances the lifeless mineral matters furnished by air, soil, and water; and it has discovered inexhaustible sources of fertilising materials, with which the exhaustion of our heavily-taxed fields may be indefinitely postponed. By its aid farmers are protected from fraud in the purchase of artificial manures and "artificial foods" for cattle. These are but examples of the benefits which Agricultural Chemistry has conferred upon the cultivator of the soil; and those who would aspire to be really enlightened agriculturists should not remain ignorant of a science so intimately affecting their pursuit.

In the following chapters we purpose describing the chemical history of the vegetable creation, in so far as it is of interest to agriculture. We shall endeavour to show how the plant grows, of what materials it is composed, and by what means its food is absorbed; and we shall point out the conditions which, according to both theory and practice, are found to be most favourable for the full development of the cultivated plants. Finally, we shall consider the means by which vegetable substances are re-organised into still higher combinations of matter—into the meat, milk, and butter which constitute so large a portion of the food of man. At present the Chemistry of the feeding-house is of equal importance with the Chemistry of the field.

The solid crust of the earth, so far as it is accessible to our research, the atmosphere which surrounds our globe, the waters which cover so large a portion of its surface, the innumerable vegetable forms which clothe and adorn the world, and the animals which find subsistence on its broad bosom, all have formed the subject of chemical investigation. Minerals, vegetables, animals, all are found to be composed of a comparatively small number of substances, termed *simple bodies*, or *elements*. Chalk is a compound mineral substance. By analysing—that is, by decomposing—it, two other substances, termed lime and carbonic acid gas, can be extracted from it. By a further analysis, lime is resolvable into a white metal, called calcium, and a gas termed oxygen; whilst from carbonic acid gas a solid substance—carbon or charcoal—and oxygen gas are obtainable. Chemical analysis shows us, therefore, that the compound mineral substance chalk is proximately a compound of lime and carbonic acid, and ultimately constituted of carbon, calcium, and oxygen.

Carbon, calcium, and oxygen are regarded as simple, or elementary substances, because up to the present no chemist has succeeded in decomposing them. Whilst we can extract from chalk, oil of vitriol, nitre, bones, starch, flesh, and thousands of other articles, from two to nearly a score of different kinds of matter, we fail in procuring from oxygen anything save oxygen, from calcium anything save calcium, or from carbon any substance except carbon.

There are known to exist sixty-three kinds of matter which resemble carbon and oxygen in being undecomposable. These are the raw materials with which Nature builds up her multitudinous structures. Some of them are found in a free or uncombined state—gold, oxygen, and nitrogen, for example—but the great majority always exist in combinations. Water is a compound of two elements—oxygen and hydrogen; oil of vitriol contains three—namely, oxygen, hydrogen, and sulphur; alum is composed of four—aluminum, potassium, sulphur, and oxygen. A large proportion of the elements occur in very minute quantities, and at present we know not the functions which they perform in the economy of Nature. Four simple substances—oxygen, hydrogen, carbon, and nitrogen—constitute the atmosphere, water, nearly half of the weight of the crust of the globe, and by far the greater part of all animal and vegetable substances. About twenty-four of the elements form the familiar objects of every-day life, and of these the greater number are found in the organic kingdoms of Nature. The

following elementary bodies have been found in vegetable substances, but some of them are only occasionally and merely accidentally present :—

ELEMENTS FOUND IN PLANTS.

Non-Metallic Elements.		*Metals.*	
Oxygen	*Essential.*	Potassium	*Essential.*
Hydrogen		Calcium	
Nitrogen		Magnesium	
Carbon		Iron	
Sulphur		Sodium	*Essentialness doubtful.*
Phosphorus		Lithium	
Silicon	*Essentialness doubtful.*	Manganese	
Chlorine		Cæsium	*Non-Essential.*
Iodine		Rubidium	
Fluorine		Copper	
Bromine	*Non-Essential.*	Lead	
		Arsenic	
		Zinc	
		Titanium	
		Barium	

Oxygen is a colourless, odourless, flavourless gas, about eight hundred times lighter than water. It exists free in, and constitutes about one-fifth of, the atmosphere. Eight-ninths of the weight of water and more than one-third of the crust of the earth are made up of this element; and it enters largely into the composition of animals and plants. This gas plays a prime part in the processes of combustion and respiration, the decay and dissolution of organic matter, and the decomposition of rocks.

Nitrogen in a free state constitutes four-fifths of the atmosphere. In combination with other elements it forms the important manurial agents, ammonia and nitre. It is a constituent of a numerous class of organic bodies, termed *nitrogenous* or *albuminous*. In a free state, nitrogen cannot be burned, neither does it support combustion or respiration. Its chief function is to moderate the action of the atmospheric oxygen, which, in a pure or undiluted condition, would act too energetically in the processes of respiration and combustion. Nitrogen is without colour, flavour, or odour, and is a little lighter than oxygen.

Hydrogen is a colourless, odourless, and flavourless gas, fourteen and a half times lighter than atmospheric air, and by far the least ponderable form of matter in Nature. It is very rarely found free. Hydrogen is inflammable, producing water by its combustion in air or oxygen. This element is an important constituent of plants, and is abundantly present in fats, oils, petroleum, and resins.

Carbon is a solid body, which, in a crystalline state, constitutes the most costly substance in commerce—the diamond. Lampblack, charcoal, coke, anthracite, and blacklead are essentially carbon. At the highest attainable temperature, this element remains infusible so long as it does not combine with other elements. Heated to redness in presence of oxygen, it unites with that element, and produces carbonic acid gas. Carbon is the characteristic element of organic bodies, as it is invariably found in every substance elaborated under the influence of the vital powers.

Sulphur is a yellow, inflammable solid, twice the weight of water. It occurs both free and combined, but much more abundantly in the latter state. Iron pyrites, gypsum (plaster of Paris), and sulphate of barium contain sulphur. Certain compounds of sulphur with oxygen and metals are termed sulphates; and some of these substances occur in soils, and furnish plants with the small proportion of sulphur which they require.

Phosphorus is an extremely inflammable substance. In colour and consistency it resembles white wax. It is seven-tenths heavier than water. Exposed to the air, it unites slowly with oxygen, forming a compound termed phosphorous acid; rapidly burned, it produces another compound with oxygen, which, under the name of phosphoric acid, is familiarly known to scientific agriculturists. This element is so inflammable that it cannot be handled without danger, and must be preserved under water. Phosphorus is never found free. In soils it occurs chiefly in the form of phosphate of calcium (a compound of phosphorus, oxygen, and calcium), but even the most fertile land seldom contains more than a half per cent. of this compound. The amount of phosphorus in whole plants probably varies from about a fourth to less than a tenth per cent.; and the proportion of phosphoric acid compounds in vegetable ashes to from 20 to 40 per cent. Sulphur compounds are less abundantly present.

The six non-metallic bodies which we have described are invariably present in plants, and they are indispensable to vegetable existence. When a plant is burned, its carbon, uniting with oxygen, passes off under the form of carbonic acid; and its hydrogen, combining with oxygen, is dissipated in the condition of water. The nitrogen in general combines with hydrogen, and produces ammonia, the "volatile alkali;" but occasionally a portion, or perhaps the whole, of the nitrogen, uniting with carbon, forms cyanogen, which generally remains as a solid ingredient of the incombustible part of the plant. The phosphorus and sulphur are, by combustion, generally converted into solid substances fixed in the fire; but occasionally a little of the sulphur may be dissipated in the form of sulphurous acid.

The substances which remain after the combustion of the plant are termed its mineral or inorganic constituents, or its ashes. They contain phosphorus, sulphur, carbon, and oxygen (in an incombustible form, combined with metals), and the metals potassium, calcium, magnesium, and iron, beside other elements, the essentialness of which is open to doubt. There are also occasionally present elements which can hardly be regarded as other than accidental impurities.

Potassium is a silvery-white metal, lighter than water. It rusts or oxidises the instant it is exposed to the air. In contact with any fluid containing oxygen, it burns with great brilliancy, evolving a rich violet light. In order, therefore, to preserve this metal, it must be covered with a layer of naphtha, a liquid which contains no oxygen. A compound of potassium with oxygen is well known under the term potash, or potassa. Potassium salts are very abundant in plants, constituting often more than half the weight of their ashes. We have made numerous attempts to grow plants in artificial soils destitute of potash, but they invariably failed, except in one instance, where rubidium, a metal which very closely resembles potassium, appeared to have been substituted for potassium. Under ordinary circumstances, however, potassium salts must be abundantly supplied to plants.

Calcium is a white metal, the oxide (oxygen compound) of which is common lime. Chalk, marble, limestone (three forms of carbonate of calcium), and gypsum (sulphate of calcium) are calcium compounds. Lime constitutes from 10 to 20 per cent. of the mineral part of plants.

Magnesium is a light white metal. It burns at a high temperature, evolving an extremely brilliant white light. Its oxide is the well-known earth magnesia. In the ashes of the seeds of plants, especially of the cereals, magnesia is abundantly present, sometimes amounting to 12 per cent. In the ashes of the whole plant, however, it seldom exceeds 4 or 5 per cent.

Iron, when pure, is a whitish metal, about seven times heavier than an equal volume of water. It unites with oxygen in four proportions, producing ferrous oxide (protoxide of iron), ferric oxide (per or red oxide), ferroso-ferric oxide (black or magnetic oxide), and ferric acid. Iron, we have no doubt, is an indispensable ingredient of plants. Kekule detected 3 per cent. of ferric oxide in the ash of gluten from wheat, and Gorup-Besanez found 68 per cent. in the ash of the fruit envelope of the *Trapa natans.* Knop could not get maize to grow when utterly deprived of iron. In general, the amount of ferric oxide found in the ash of plants is under 1 per cent., and proportions exceeding that amount are probably useless.

Sodium is a whitish metal, very little lighter than water. It resembles potassium in many respects, but it does not quite so rapidly tarnish as that metal. Its oxide is termed soda (sodic oxide), and its compound with oxygen and carbon is the well-known carbonate of soda—in modern chemical language, sodic carbonate. Common culinary salt is a compound of sodium with chlorine. Here we should explain that none of the metals, except small quantities of iron, found in plants occur in an uncombined state in Nature.

Although sodium compounds are generally, and often very largely, present in plants, yet we are quite satisfied that this metal is neither indispensable nor useful to vegetables. The results of the experiments of Knop, Nobbe, Peligo, Siegert, and other chemists sustain this view. Our own experiments, con-

ducted during several years, and performed with various species of plants, lead to the conclusion that sodium compounds are not requisite for the full development of plants (see *Chemical News*, May and June, 1862). On the other hand, Stohmann, the Prince of Salm-Horstmar, and other investigators, assert that sodium compounds are indispensable to plant life; though they have to admit that only the merest traces are often present in healthy and fully-matured plants. It may be said that as sodium compounds (common salt, for example) are indispensable to animal life, Nature would have furnished a sufficient supply of it, as well as of the other principles of food, through the agency of the vegetable kingdom. It must, however, be borne in mind that, with the exception of water, common salt is the only mineral food which animals use; for every other food substance is, directly or indirectly, derived from plants. If Nature intended that salt should be an indispensable constituent of vegetables, animals would not have been endowed with an instinctive longing for the mineral form of that substance.

Lithium, cæsium, and rubidium are three metals allied (especially the latter two) to potassium. They are widely diffused throughout Nature, but they occur in excessively minute quantities. We have found them in several vegetable substances, but they are not invariably present, and in all probability they are not essential ingredients of plants. Salm-Horstmar, however, believes lithium to be useful in the flowering of certain plants. The remarkable resemblance between potassium and rubidium and their compounds renders it probable that the latter might be capable of replacing wholly or partially the former as an ingredient of plants.

Manganese is a metal somewhat allied to iron, and often found associated with the latter. Salm-Horstmar believes the oxide of manganese to be an indispensable ingredient of plants. Such, however, is not our opinion, for we have often found whole plants completely free from even traces of this substance.

The metals aluminum, barium, copper, lead, arsenic, zinc, and titanium have been detected in plants, but their presence therein must have been purely accidental.

The non-metal, silicon—or rather its compound with oxygen, silica—is invariably found in all plants grown under natural conditions. Sachs, Nobbe, Knop, Siegert, Rautenberg, Stohmann, Kühn, Birner, Lucanus, and others, have notwithstanding, grown plants of various kinds with perfect exclusion of silica, and apparently without injury to the plants. Pierre has proved that the common opinion, attributing the "laying" or "lodging" of corn to a deficiency of silica in the straw, is not founded on facts. It appears probable that, if silica be really requisite for plants, a very small proportion of it only is necessary. Silicon is a chemical curiosity, never being found in a free state. It occurs either as an olive-brown powder, or in the form of very hard brownish crystals. Its compound with oxygen is termed silica, silex, or silic acid. Rock-crystal is very pure silica; in a less pure state silica exists as quartz, jasper, agate, and flint. Most rocks and soils are largely composed of silica.

Chlorine gas is a yellowish-green, non-metallic body, possessed of a powerful and disagreeable odour. It is twice and a half the weight of atmospheric air. The bleaching and disinfecting properties of this gas—and of its compound, chloride of lime, or bleaching powder—are well known. Chlorine, united with potassium or sodium, is rarely, perhaps never, altogether absent from plants. Except in the case of marine and sea-side vegetables, it seldom constitutes more than 1 per cent. of the ashes of plants. Many of the most distinguished agricultural chemists assert that chlorine is not one of the necessary ingredients of cultivated plants.

Iodine is a black, solid non-metal, about five times as heavy as water; its odour somewhat resembles that of chlorine largely diluted. Its vapour possesses a splendid violet colour. In seaside plants it is found in somewhat large proportions, and it is prepared from the ashes of sea-weeds. It rarely occurs in cultivated plants, and even in the case of marine vegetables we believe that it is not indispensable.

Fluorine (a non-metal, as yet not satisfactorily isolated) is believed by Salm-Horstmar to be indispensable to vegetable life. It is, however, certain that the quantity of this element hitherto found in plants has been quite insignificant.

Bromine (a liquid resembling in its chemical relations chlorine and iodine) has been detected in plants; but there can be little doubt as to the accidental nature of its occurrence in the vegetable kingdom.

With the exception of sulphur, all the non-metals found in plants exist naturally in combination with other elements, and it is only by means of the chemist's art that these elements have been exhibited to us in their free or uncombined state.

The average amount of carbon in dried plants is about 47 per cent.; of oxygen, 42 per cent.; of hydrogen, 6 per cent.; of nitrogen, 2½ per cent.; and of ashes, 2½ per cent.

TECHNICAL EDUCATION ON THE CONTINENT.—I.

BY ELLIS A. DAVIDSON.

TECHNICAL EDUCATION GENERALLY.

THE purpose of the present series of papers is to give an account of the rise and progress of Technical Schools on the Continent, their systems of management, their courses of instruction, and such other particulars in connection with them as have been gleaned by personal inspection, correspondence with the professors, and from documents furnished by the local authorities of the various institutions.

From a careful study of the general constitution of these important schools, from an investigation of the intellectual ground they cover, and from the facts, details, and results which will be here presented, it is hoped that additional impetus may be derived in the promotion of technical education in this country.

Before, however, entering upon the general consideration of the subject, it is necessary that the real meaning of the words "technical education" should be in some degree made clear. The term has been so bandied about, so misapplied, and so misunderstood, that many who really stand in need of such a course of training are now asking, "What *is* technical education?"

Technical instruction, then, may be briefly defined as the application of the great principles of science to the various branches of industry; it gives, in fact, a knowledge of practical science and art, adapted to the required purposes, and to the conditions imposed by the nature of the materials employed; and it teaches the principles upon which the processes of working are based, of what nature soever the occupation of the worker may be.

It will be seen, then, that technical instruction cannot be taken as a distinct and separate branch; it must grow out of, and depend entirely upon, a sound elementary education, and a knowledge of the fundamental principles of science. To attempt technical instruction, therefore, without this basis is as absurd as to build and decorate a house without provision having been made for the security of the foundation.

Taking up the subject, as we have only recently done in this country, after long years of neglect, we must do the best we can with our artisans whose elementary education is deficient, and whose time for study is necessarily very limited. The work requires, therefore, the earnest exertions of authors, in the compilation of text-books of such a character as shall teach the rudimentary principles of science and art, and also show their practical application in the simplest manner; it requires the enterprise and energy of publishers, in the production of such works; and it requires the greatest tact on the part of our lecturers and teachers, in popularising and simplifying those studies which their adult students have become accustomed to regard as abstruse and difficult, and which they consequently approach with fear and dread. These students require cheering and encouraging by the way; they require that the obstacles and roughnesses which obstruct their path should be removed or smoothened down; they truly want "words to guide and hands to lead;" and it is to assist both teachers and pupils in this great work, that the lessons put forth in the TECHNICAL EDUCATOR, and in the Technical Manuals, have been compiled.

As regards our youths, however—admitting the early age at which they are generally taken from school—a sound primary education is now within the reach of all; and this will, it is hoped, be soon greatly improved, so as to become the basis for a higher system, to be carried out either in the day-schools or in the science classes which are happily spreading all over the country.

With the view, then, of encouraging working men and others to take up the various branches of study promulgated in these pages, and in the hope of inducing them to give their children —for it is scarcely now a question of means—a sound primary education, as the best foundation for a technical course, the detailed plans of study on the Continent are given. At this stage no comment on these systems will be made, such being reserved until the programme of the studies of each Continental school and institute is before the reader. A comparison of these with the classes held in our mechanics' institutions, with some exceptions, may, perhaps, furnish some food for reflection as to the failure of so many of these institutions in this country, whilst they flourish luxuriantly abroad.

Before, however, we can fairly appreciate the value of the systems pursued on the Continent, and derive practical advantage of the knowledge gained, we must review the former and present position of technical instruction in England.

It was immediately after the great International Exhibition of 1851 that Dr. Lyon Playfair published his report on the state of technical education on the Continent; and in a communication made more recently to Lord Taunton, on "The Industrial Arts of Great Britain," as exemplified in the Paris Exhibition of 1867, the learned professor states that, "with very few exceptions, a singular coincidence of opinion prevailed that our country had shown but little inventiveness, and made but little progress in the arts of industry since 1862."

All who are sensible of Dr. Playfair's comprehensive knowledge of the subject, his warm interest in everything that concerns the intellectual development of his fellow-creatures, and his unswerving truth, must feel grateful to him for thus calling public attention to a great national deficiency, and so enabling us to devise means which shall prevent our being intellectually lowered in the scale of nations, and which shall bring about a system of education so healthy and sound as to have a practical bearing on the trade, manufactures, and commerce of our country.

The Exhibition of 1851 showed us that in ornamental art as applied to manufactures we were behind other countries, and the notion obtained that we were essentially a nation of shopkeepers—a people devoid of taste; but, on investigation, it soon became evident that we were not so deficient of taste as of art education. The Government Department of Practical Art was instituted, teachers were trained and spread over the length and breadth of the country, Art was made popular, and the application of its principles to trade purposes was shown. It is now admitted on all hands that the seeds thus broadly sown have fructified fairly, and that in the period which has since elapsed a great and permanent improvement has been made.

Daily is this progress becoming more evident, and daily is the measure of success increasing, because, in addition to the Schools of Art, which are intended for youths and adults, the teaching of elementary freehand drawing, geometry, and model drawing has, since 1852, been actively carried on in most of our National and British Schools, by teachers who have been taught elementary practical art in the colleges in which they were trained, or by the masters and assistants of the neighbouring Schools of Art. And thus the system, *because it begins at the root*, and provides for primary instruction, prospers. These pupils grow up, they feed the classes in the art schools, and the result is a trained body of designers and art workmen, who are fast supplying the designs and executing the works which were formerly imported from abroad.

It has, however, now become evident that a corresponding progress has not taken place in the scientific and mechanical branches of industry, and this must, no doubt, be attributed to the unpractical character of the elementary education given in most of our primary and other schools, which renders much of the teaching of the science classes recently established unavailing to adult students, whose elementary education has been of such an inefficient character that many of them cannot follow or take notes of the clearest lecture, or spell even the simplest scientific terms; and whilst some of them have learnt Euclid (*from the book*), they have never obtained any idea of the practical use of the study of Geometry.

It is with the view, therefore, of showing how education, to be ultimately useful, must, from the very beginning, be of a defined character; how the tendency of all teaching, from the moment that the tools to be used in the acquirement of knowledge—reading, writing, and elementary arithmetic—have been mastered, should be such that every lesson may be a part and parcel of a course to be subsequently carried further—even as every brick, however low may be its situation in a wall, supports others in the superstructure—that the plans carried out in the different grades of schools on the Continent will be here described.

Before, however, proceeding to show the courses of education open to working men and their children abroad, let us glance at the early instruction and apprenticeship of an English artisan.

As a boy, he attends a National or British School, where he may be, and in most cases *is*, well taught by a man who is earnest, energetic, self-sacrificing, and conscientious. But the course of study and the standards of examination are fixed by the Education Office, and the income derived from that source is dependent on "results." The master cannot, therefore, afford that time should be devoted to other branches—in fact, some find it difficult to allow even one hour per week for drawing. Again, in many cases the masters are not competent to give a technical tendency to their teaching, their own education having been merely literary in its character; some are, in fact, unacquainted with the commonest principles of construction and mechanism, although they may have *read* the science of Mechanics. Their own education having been purely theoretical, and as young men are appointed to schools in different parts of the country by the authorities of the training college in which they have resided, sometimes being posted in neighbourhoods wholly new to them, they are in most cases unacquainted with the processes carried on in the industries of the locality, whilst the elementary principles upon which these are founded should certainly form branches of study in the school. Elementary Chemistry, Geology, Metallurgy, Economic Botany, etc., are not amongst the subjects aimed at in our primary schools, and thus the children do not acquire a knowledge of the sources or qualities of the raw materials in which they may subsequently have to work. Even "object cases" do not form a general portion of school apparatus, and the lessons given on their contents are desultory and unsatisfactory.

The natural and unavoidable consequences of such a state of things is that, excepting in some of our ragged and industrial schools, where gardening, shoemaking, tailoring, etc., are carried on as *occupations*—not as studies, but merely classed with wood-chopping—the boy leaves school without having received any notions of what may be called the theory of work, or of the sciences upon which the practical arts are based, thinking of Chemistry as a mysterious art by which the *druggist* compounds medicines, and naturally associating *Physics* therewith. He looks upon a locomotive as a machine which somehow or other pulls the train along; and building is to his mind merely the work of the mason, bricklayer, and carpenter.

As a rule, chance, not talent or predisposition, guides the placing of the boy in an occupation by which he is to earn a livelihood, the parents being naturally anxious to send their sons out, so that their earnings may assist in the maintenance of the family.

Let us follow the boy, and see him placed in an engineer's or railway works. He is in most cases merely an errand boy, or fag, being fit, in fact, for little else. He is subsequently posted in one of the departments, his instructor being the man under whom he works; but this man having his own work to attend to, has not time to teach, and even were it not so he could only show the boy the manual operations. It is but rarely that a boy placed in such a position will have been able to acquire any of the scientific principles of his trade; some brilliant exceptions there are, of course, but this is the general rule.

When the piece of work on which the apprentice has been engaged is finished, it has to pass the foreman of the department, generally a man who, through honesty, sobriety, and manipulative skill, has risen from the ranks of the workmen, and whose education has been of a character similar to those around him. The foreman's duties, of course, leave him no time, even if he were competent, to give instruction, and thus the lad goes on. In time he becomes a journeyman—he may become a foreman, to govern others. Thus the "rule of thumb" —viz., each man working as his shopmates do—proceeds, and thus has ignorance of principles been carried on from one generation to another.

VEGETABLE COMMERCIAL PRODUCTS.—I.

INTRODUCTION.

A PLANT is only earth and air, transmuted into those *nutrient* principles which form the food of animals. Plants form the basis of organised life. In the great laboratory of Nature they are employed in supplying the atmosphere with oxygen, and in removing its carbonic acid. No true naturalist will speak of any portion of the vegetable world as useless weeds.

But there are some plants which are especially useful to man, as sources of food, clothing, and medicine; and others are very valuable, as furnishing building materials, barks, gums, resins, balsams, dyes, oils, and perfumes. These plants are found in different countries and climates, to which, by a wise arrangement of Providence, they have been restricted. It is natural and useful to inquire, "From what countries are they brought? What quantity of them is annually imported? What are the economic uses made of their products?" Obviously, the pursuit of such inquiries must open a wide and instructive field of research.

Numerous as are the vegetable products, hitherto discovered, capable of utilisation, they are few when compared with the inexhaustible wealth of Nature. Not a year but adds in this respect something to our knowledge. When public attention shall be fully directed to this subject, an immense harvest will be reaped. Our limits will only admit of the discussion of the most valuable of them. They may be subdivided into two groups—1. Food Plants; 2. Industrial and Medicinal Plants.

1. RICE (ORYZA SATIVA). 2. MAIZE (ZEA MAYS).

FOOD PLANTS.

I. FARINACEOUS PLANTS.

The grasses (natural order, *Graminaceæ*) constitute one of the largest and most widely distributed of the natural orders of plants appearing in temperate climates in numbers so vast that they form the principal mass of the verdure which covers the landscape. The grasses of tropical climates are generally much loftier than those of the temperate zones, less gregarious, and more tufted. We give the first consideration to the Cerealia, or corn plants, the caryopsis or grain of which contains an abundant farinaceous albumen, capable of great improvement in quantity and quality. The Cerealia have been cultivated from the remotest antiquity, and were thought by the ancients to be the gift of the goddess Ceres. Their native country is unknown, and they have been so changed by cultivation, that we are ignorant, except in one or two plants, of the wild stock from which they are lineally descended. The Cerealia of temperate climates include the European cultivated grasses, wheat, oats, barley, and rye; maize and rice are the chief cereals of the tropics.

(*a.*) *The Cerealia of Temperate Climates.*

WHEAT (*Triticum vulgare*, Linnæus).—Wheat is the chief grain of temperate and sub-temperate climates. Its geographical range extends from 30° to 60° N. lat., and 30° to 40° S. lat., in the Eastern continent and Australia. Along the Atlantic portions of the Western continent the wheat region embraces the tract lying between 30° and 50° N. lat. In the tropics, wheat is cultivated only in mountainous districts, where the land is sufficiently elevated to be of the proper temperature. It is estimated that in Great Britain 5,000,000 acres are annually covered with this grain.

Wheat is imported into the United Kingdom chiefly from Europe and America. We get red and white wheat from Prussia and Austria, Spanish wheat from Bilbao, and Saxanka wheat from St. Petersburg. We also import largely from the United States, Turkey, and Egypt. The finest kind of European wheat is from Dantzic, the grain being large, white, and very thin-skinned. 34,645,569 cwt. of wheat were imported in 1867. The largest amounts were received from the southern parts of Russia, Prussia, and the United States.

Wheat was formerly sown broadcast—that is, thrown from the hand of the sower over soil previously prepared by the plough. This is the most ancient mode. In modern times the plan of drilling or dibbling has been adopted—that is, depositing the seed in holes, formed in straight furrows at regular intervals.

When wheat is crushed between the stones of the mill, it is separated into two parts, the bran and the flour. The bran is the outside harder part or coating of the grain, which, intermingled with the flour, darkens its colour, and is generally sifted or bolted out to a greater or less extent. Bran is used for fattening the stock on the farm, and is of some commercial value in tanning, calico printing, for filling dolls, cushions, etc. The finest kind of bran is called middlings. Pollard is a coarse product of wheat from the mill, but finer than bran.

The whole meal, or the mixture of flour and bran obtained by simply grinding the grain, is as nutritious as the grain itself; and as bran is an alimentary substance, and equal to one-fourth the weight of the whole grain, by its separation much waste of wholesome food is caused. The great importance attached to bread perfectly white is a prejudice. Brown bread, made from the whole meal, should be adopted not merely on a principle of economy, but as containing the most nutriment.

Flour is largely imported from California and other parts of the United States. We received in 1866, from all sources of supply, 4,972,280 cwt.; but in 1867 only 3,592,969 cwt.

OATS (*Avena sativa*, L.).—The oat is the hardiest of all the cereal plants, and one of the most elegant of grasses. It can be cultivated in countries where wheat and barley will not grow. Its adaptability to climate is so great that it is cultivated in Bengal as low as 25° N. lat., but it refuses to yield profitable crops as we approach the equator. The oat is cultivated in England, principally in the north and north-eastern counties, and in most parts of Wales and Scotland. It grows luxuriantly in Australia, in Northern and Central Asia, in South America, and over the whole of the cultivated districts of North America.

The meal of this grain is remarkable for its richness in gluten, and for containing more fatty matter than any other of the cereals. To these two circumstances it owes its nutritious and wholesome character. It is therefore very suitable, and much in use, as an article of diet for invalids. The variety called the potato-oat is a great favourite in Scotland, and is

almost the only kind now cultivated there. Oatmeal forms a very considerable portion of the daily food of the Scotch, and oat-cakes are much eaten in the northern counties of England.

We export no oats, as our domestic consumption is equal to the amount grown. The crop of this grain annually raised in the United Kingdom is twice as large as that of wheat.

The use of the oat is very ancient. It is not mentioned in the Bible, but it is alluded to by the Greek and Roman writers, Dioscorides and Pliny. Caligula is said to have fed his horses with gilded oats; but this report was probably an allusion to the colour of the grain. 9,407,136 cwt. of oats were imported into the United Kingdom in 1867. The greatest quantities came from Russia, Sweden, and British North America.

BARLEY (*Hordeum distichon*, L.).—This grain is one of the staple crops of Northern Europe and Asia, growing as far north of the equator as 70°, and as far south of it as 42°, in favourable seasons and situations. In the New World its growth is chiefly confined to Mexico, the middle, western, and northern States, and Canada. In Asia, it is cultivated in the Himalayas and Thibet, replacing wheat in many districts, and producing admirable flour.

Barley is chiefly used for malting and distilling purposes, in making beer and spirits. When the outer coat of this grain is removed, it is called pearl barley, and in this form it is valuable for thickening broths and soups. Barley-water is a mucilaginous drink for invalids, made by boiling pearl barley.

About 10,000,000 quarters of barley are grown annually in the United Kingdom. Our imports of this grain in 1866 amounted to 8,433,863 cwt., but in 1867 to only 5,683,721. The greatest quantities were received from Denmark, Prussia, France, and Turkey proper.

Barley is a very ancient article of human food. It is mentioned in the Bible in the book of Exodus. It has been cultivated in Egypt and Syria for more than 3,000 years. Pliny calls barley the most ancient food of man. It requires very little dressing when sent to the mill, having no husk, and consequently no bran.

RYE (*Secale cereale*, L.).—This is a highly nutritious grain, but not much raised in this country, except as green fodder for cattle. In Bohemia and most parts of Germany, however, rye forms the principal crop. It is also much cultivated in the north of Europe, and in Flanders, where, mixed with wheat, and sometimes with barley, it forms a leading article of subsistence. The peasantry of Sweden live very generally on rye-cakes, baking them only twice a year; they are, therefore, the greater part of the time as hard as a board. Geographically, the diffusion of rye and barley is pretty much the same, as these plants generally grow in similar soils and situations.

Rye-straw is useless as fodder for cattle, but forms excellent thatching material, and a superior article for stuffing horse-collars, so that saddlers will usually pay a good price for it. The amount of rye imported in 1866 was 368,392 cwt.

Rye is much infested by a very poisonous fungus. When attacked in this manner, it is called in England "horned rye," and in France *ergot*, from a fancied resemblance to a cock's spur. The poisonous influence of this fungus extends not only to human beings, but insects settling on it are killed, and swine, poultry, and other animals, die miserably in strong convulsions, and with mortifying ulcers. Ergot of rye is, however, in the hands of a skilful physician, useful as a remedial agent.

The principal granaries of Europe are Hungary, Russia, Moldavia, and Wallachia; and the chief ports for the exportation of grain, Archangel, St. Petersburg, Riga, Konigsberg, Dantzic, Stettin, Rostock, Kiel, and Hamburg, in the north, and Taganrog, Kertch, Odessa, and Trieste, in the south. Large flour mills have been recently erected at Mayence on the Rhine, which is now a very important place for this branch of commerce.

(*b*.) *The Cerealia of Warm Climates.*

RICE (*Oryza sativa*, L.).—This useful grass is a native of the East Indies, whence it has spread to all the warm parts of Asia, Africa, and America. It is a marsh plant, and grows very much like the oat, the grain hanging gracefully from the very thin, hair-like pedicles, forming a loose panicle. Rice is cultivated throughout the torrid zone, wherever there is a plentiful supply of water. Under favourable circumstances it matures on the Eastern continent as high as 45° N. latitude, and as low as 38° S. latitude. Its cultivation is principally confined to India, China, Japan, Ceylon, Italy, Madagascar, South Carolina, and Central America.

The rice from the Southern States of America is decidedly the best, being much sweeter, larger, and better coloured than that from Asia, where its cultivation is not so well managed. It is necessary to except Bengal rice, which now nearly equals that growing in the Carolinas. South Carolina produces the best American rice, and Patna the best East Indian variety. Excellent rice is also grown in the Spanish provinces of Andalusia, Valencia, and Catalonia, as well as in the marshes of Upper Italy, especially Lombardy and Venice, and in the plains of Milan, Mantua, Verona, Parma, and Modena, along the river Po.

In 1867 we imported 2,785,423 cwt. of rice, besides 44,943 qrs. in the husk. Most of our rice comes from the British and Dutch East Indies, the Carolinas, Brazil, and Egypt.

The Carolinas and Louisiana now produce annually about 800,000 cwt. of rice, of which 300,000 cwt. are exported *viâ* Charleston and New Orleans; the Brazilian rice comes into commerce from Rio Janiero, and the Egyptian (500,000 cwt.) from the Delta of the Nile, *viâ* Damietta and Rosetta.

Immense quantities of rice are consumed in England in the form of puddings and confectionery. The straw is plaited for bonnets. Rice-paper is not manufactured from this grain, but is the pith of a shrub called by the Chinese "taccada," and by botanists *Aralia papyrifera*, L. The pith, carefully removed from the stem of this plant, is first cut spirally with a sharp knife, then unrolled, spread out, and pressed flat. This paper is much used by the Chinese for water-colour paintings of insects and flowers.

Rice, although regarded by us more as a cheap luxury than a necessary article of food, forms the chief subsistence of the Hindoos, Chinese, Japanese, and other Eastern nations. The Burmese and Siamese are the greatest consumers of this grain. A Malay labourer requires 56 pounds monthly; but a Burmese or Siamese 64 pounds. The people of South Carolina do not consume much rice themselves; they raise it principally to supply the foreign demand, the swamps of that State—both those which are occasioned by the periodical visits of the tides, and those which are caused by the inland flooding of the rivers—being well suited to its production. The mountain-rices of India are grown without irrigation, at elevations of 3,000 to 6,000 feet above the level of the sea; the dampness of the summer months compensating for the want of artificial moisture.

Rice which comes to us in the husk is called by its Indian name "paddy." Before it can be used for food this husk must be removed; this is done in India amongst the poorer people by rubbing the grain between flat stones, and winnowing or blowing the husks away. Paddy is now imported into the United Kingdom in larger quantities than it used to be, though preference is still given to rice in its shelled state. In 1856 32,694 qrs. of rice in husk were imported to 3,692,001 cwt. of shelled rice; while in 1863 the relative proportions were only 152 qrs. of the former to 3,070,292 cwt. of the latter. In 1868 45,404 qrs. or about 252,308 cwt. of rice in husk were imported to 4,735,997 cwt. of shelled rice.

The cultivation of rice undoubtedly dates from the oldest period of which we have any historical record. "Cast thy bread upon the waters, for thou shalt find it after many days" (Eccles. xi. 1), evidently applies to rice, which in Egypt is always sown whilst the waters of the Nile still cover the land, the retreating floods leaving a rich deposit of thick alluvial silt, in which the rice vegetates luxuriantly. A spirituous liquor (*arrack*) is distilled from rice.

MAIZE, or INDIAN CORN (*Zea Mays*, L.).—This plant has a strong reedy-jointed stem, as thick as a broom-handle, with large alternate leaves springing from each joint. In favourable situations this stem attains a height of from seven to ten feet; it terminates in a large compound panicle of male flowers called the *tassel*. The female flowers are situated below the male, and spring from the sides of the stem. They consist of ten or more rows of grains or caryopses, situated on the surface of a thick cylindrical pithy axis or stem called the *cob*, from eight to ten inches in length. From each of these grains proceeds a long hairy filament, the whole cob being enveloped by several layers of thin leaves, forming the husk or wrapper. The filaments of the individual grains hang together in a thick cluster out of the husk, and are called the *silk*. The filaments receive the pollen or fertilising matter from the anthers of the *tassel*;

a fact easily proved by cutting off the tassel, when the ears prove abortive. After fertilisation, both tassel and silk dry up. This plant, when grown up to some height, usually sends out several suckers from the lower joints of its stem, which help to maintain its upright position, acting as props or buttresses.

Maize may be raised on the American continent as far to the north and south of the equator as the 40th parallels of latitude, whilst in Europe its geographical range on either side of the equator extends even to 50° and 52°.

Naturalists are at no loss to determine the native country of maize, which is undoubtedly America, as the Indians throughout the continent were engaged in its cultivation when the New World was first discovered. It now forms the staple grain crop of the United States and Mexico. Since the discovery of America, maize has been introduced into the Old World, and is now grown abundantly in Hungary, Transylvania, Moldavia, and Wallachia. From these countries large quantities are annually sent down the Danube, *viâ* the Wallachian port and fortress of Galatz, into the Mediterranean as far as Malta and Trieste. Maize is also largely grown in the countries around the Mediterranean, and in Southern Germany. It is raised in India, the East Indies, and in Australia; in a word, in all those regions of the tropical and temperate zones where the white man has established himself.

Like the other cereals, maize may be reduced to meal, the coat of the grain or bran remaining mixed with the flour. Owing to its deficiency in gluten it is not much used for making bread. In the United States, however, it is made into cakes, and eaten under the name of "corn bread." In this country it is not regarded with much favour as human food, although it is both sweet and nutritious. We import it largely from America, principally for feeding and fattening cattle. In the preparation called *hominy*, the grain is first soaked, and then exposed to a dry heat, which causes the bran or outer coat of the grain to crack and peel off, when it is easily separated. *Pop-corn* is another American preparation of maize made by slightly baking the unripe grains. The corn cobs form a very cheap and useful fuel. We imported in 1866 14,322,863 cwt., and in 1867 8,540,429 cwt. of maize, chiefly from the United States and the Turkish dominions.

Guinea Corn, Durra, or Turkish Millet (*Sorghum vulgare*, Pers.).—"A roundish grain, in shape not unlike maize, but not of greater bulk than a small grain of wheat; its colour is a yellowish-white. It is borne in loose tufts or panicles; the stalks are about eighteen inches to two feet in height, and when dry are very rigid; in this state they are much used in the manufacture of carpet-brooms and whisks. The grain itself is chiefly used in this country for feeding poultry; it is, however, strongly suspected that wheaten flour is not unfrequently adulterated with it, but this can only occasionally take place, as the importation of *durra* is very irregular. It is much used as food for the black population in the West Indies, whence it has been called *negro* corn; they make of it cakes about an inch thick, which are white, and tolerably palatable. It is also used by the poorer peasants of Italy. We receive it chiefly from Northern Africa; it is, however, cultivated largely in the United States, West and East Indies, and in Southern Europe. India is its native country." (Archer's "Economic Botany," p. 8.)

AGRICULTURAL DRAINAGE AND IRRIGATION.—I.

By Professor Wrightson, Royal Agricultural College, Cirencester.

INTRODUCTION—DEFINITIONS OF DRAINAGE AND IRRIGATION—EARLY HISTORY OF THE SCIENCE.

Agricultural drainage may be defined as the art of freeing land from superfluous water. In its more restricted sense it has reference to the improvement of land already under cultivation; in a more extended signification it includes the reclamation of land from the sea and the drainage of lakes and marshes. Viewed in connection with the natural drainage of the country by means of rivers, artificial drainage becomes of high importance as the art of improving natural outfalls; and when used for this purpose the term *trunk* drainage is applied, in contradistinction to *underground* drainage, by which is meant the more localised use of the art in draining wet soils. Although to the landowner or occupier the drainage of land surcharged with water by means of pipes may appear the more important, yet the first place must be given to trunk drainage, since without a perfect river economy much of what is now available land would be a mere swamp. Rivers may, indeed, from the drainer's point of view, be looked upon as gigantic "main drains," into which smaller streams, brooks, brooklets, and ditches, empty themselves. The series thus sketched out is rendered complete by the underground pipe drains laid in every furrow. The whole system may, indeed, be compared to a tree, the smallest twigs of which are represented by the furrow drains: just as the sprigs gradually unite into larger twigs, branches, and boughs in passing to the trunk, so in the case of land drainage do we find drains discharging into water-courses, these again into brooks and streams, which finally add to the bulk of some important river. Looking at drainage from this extended view, it at once assumes a national importance. Not only is it a means of enriching landlords and farmers, or giving an increased supply of food to the population, but it vitally affects the whole question of the water supply of the country. There is also the sanitary aspect of the drainage question, which adds to its interest and importance. Of late years much attention has been given to urban drainage, and through the value of sewage as a manure there is a close connection between this section of the subject and agriculture, insomuch that the sewage question is keenly watched and discussed by agriculturists. The climate of large districts of the country is altered and improved by the drainer's art, and instances are not wanting of certain diseases having disappeared from localities where drainage works have been extensively carried out. Hence, from an agricultural, national, and sanitary point of view, drainage is a subject of vast importance, and well deserves our close consideration.

Irrigation may be spoken of as the art of carrying water on to land in order to increase its fertility. This art has been practised from the earliest historical times in all civilised countries. Water-meadows have been established in this country for hundreds of years, but of late public attention has been aroused to the importance of still further extending the area of land thus treated. Although drainage and irrigation appear at first sight to aim at two opposite objects—the first to take water from the land, and the second to cause water to flow into it—yet they must not be looked upon as antagonistic. It may, indeed, be readily shown that, while draining frees land from superfluous moisture, it is the means of causing a larger body of water than formerly to pass through any given section of the soil. The same rainfall descends upon the drained as upon the undrained field, but owing to the arrangement of underground channels there is in the former case no puddling of the surface, no trickling *over* the land into contiguous ditches, evaporation is checked, and the land is dry because the water has *quickly passed through it*. Drainage, therefore, is a means for altering the condition of water in the soil, rather than of depriving the soil of so valuable an element of fertility. By it a stagnant condition is changed into a state of movement, and the full advantages of the rain are realised. Without it the land is waterlogged, and showers which ought to find their way down to the roots of plants soak the surface and feed the neighbouring gutters. The benefit of irrigation may likewise be traced to the constant change of the water as it passes over the surface of the meadow, giving up its riches to the herbage over which it flows. Thus drainage and irrigation may be shown to have much in common, and the idea of their being opposed to each other may be dispelled. Nay, further, as a preparatory step in the formation of water-meadows, it is often considered advisable to under-drain the field, thus showing that the two operations, so far from neutralising, may assist each other in improving the same land.

In considering such a subject as agricultural drainage and irrigation, we shall postpone the treatment of the latter for the present. Drainage may best be viewed, first, from a theoretical, and, secondly, from a practical point of view. After a few remarks on the history of the art, we shall proceed to the study of the *theory* of drainage, which comprises the reasons of its efficacy, and the study of the action of drains in soils of varying character. To thoroughly understand this part of our subject, considerable knowledge of Physics, Chemistry, and Geology is needed, all these sciences bearing directly upon it.

The practice of drainage will include a description of the various systems in vogue, a consideration of the materials fitted

for underground channels, the mode of carrying on the work, the practical good effects which may be expected to follow the operation, and the cost.

In treating of the history of drainage we shall be brief. Those who wish to study this subject fully will find abundant information, of a somewhat prosy character, in "The History of Embanking and Draining divers Fens and Marshes, both in Foreign Parts and in this Kingdom," by William Dugdale, Esq., Norroy King-at-Arms. In this work the earliest accounts of drainage, from the draining, embankments, and outfalls used in the economy of Egyptian agriculture down to the Christian era, are given; and the author cites the names of Mysis, Sesostris, Sabacon, Darius, Amasis, Alexander, the Ptolemies, Cleopatra, Cæsar Augustus, etc., as among the patrons of this useful art. To us it is more interesting to learn that the Belgic drainage works were commenced about the year 863 A.D., by Baldwin I., son-in-law of the Emperor Charles the Bold, who undertook the work of reclamation in the neighbourhood of Bruges. We also find that a marsh common law existed as early as 796 A.D. in this country, in which powers for levying rates were conferred. In the reign of Henry III. Henry de Batho framed ordinances which settled the laws and customs of Romney Marsh on the occasion of a threatened irruption of the sea through the sea-wall. Such facts sufficiently demonstrate the antiquity of drainage and reclamation on a large scale. It is hardly necessary to trace the history of the gradual change of the fen lands of the eastern counties from the home of fish and wild fowl to their present high value as corn-growing districts. The work has been accomplished by the individual energy of private individuals, by Dutch settlers, and by the powerful house of Bedford. In tracing the history of drainage we find that, although the art was understood and practised even in the most ancient times, the subject for improvement was always submerged or marshy land. If we seek for the origin of modern ideas upon drainage we shall find little mention made of the drainage of land already under cultivation, as a further improvement, until comparatively recent times. This is well exemplified by the following quotation from the late Thomas Gisborne's excellent essay on drainage, which first appeared as a contribution to the *Quarterly Review*, and was afterwards revised and published with several other essays on agricultural subjects. After stating that the first phase of the controversy between agriculture and water might rather be described as the recovery of land than its improvement, he says: "Two other cases remain in which water appears as an opponent of agriculture. The first is that in which rain, falling on pervious lands, filters through them and reappears in the shape of springs on the surface of lower lands not equally pervious, much to their injury. The second is the case of lands which, from closeness of texture, are not able to pass down the rain which falls upon them. The combat with these two cases marks two distinct eras in the history and progress of drainage."

We must view the adoption of covered drains as an improvement upon the more ancient and simple open ditch. Both plans are, however, old, and both were used by the Romans, as appears from the writings of Cato, Varro, Columella, Pliny, and Palladius. The energy of the Romans was, however, principally directed against soils wet from springs, or the filtration of water from a higher level, and they do not appear to have attempted the improvement of soils of a more tenacious character, wet from their own inherent imperviousness.

In tracing the history of English drainage down to the present time, it is striking to note how completely the drainage of cultivated land is a modern notion. Fen lands and marshes were early reclaimed, and from time to time a note of warning was sounded, urging the importance of a more close attention to this means of utilising waste lands. Mr. Fitz Herbert, who wrote on agricultural topics in 1534, says, "There is none other remedy for marrys ground but first to drain the water clean away," and this has to be accomplished by means of open ditches, having an outfall into larger or main ditches. "And," says he, "if this manner of ditching will not make the marsh ground dry, then must you make a slough (drain or hollow ditch) underneath the earth; and if that will not serve, then keep out your cattle for fear of drowning."

The earliest notice, says Mr. Gisborne, that we have of English draining is contained in a broadside in Vol. IV. of the "Collection of Proclamations, etc.," once belonging to James II., and now in the library of the Society of Antiquaries, London. "Herein," says the writer, who dates from Paine's End, November 16, 1583, "is taught, even for the capacity of the meanest, how to drain moores and all other wet grounds or bogges, and lay them dry for ever." It is also directed that the drains should be shallow, arranged in a herring-bone pattern, and filled with stones.

Captain Walter Blythe published his "Improver Improved" in 1640, and Andrew Yarranton (see page 22) wrote, in 1677, "England's Improvement by Sea and Land." Both were authorities on draining, and the former has been frequently quoted to show how little the last two centuries have done to improve the drainer's art. Blythe describes in somewhat quaint language the essentials to success in draining wet soils, when he says, "And for thy drayning trench it must be made so deepe, it go to the bottome of the cold spewing moyst water that feeds the flag and rush . . . . and a yard or four feet if ever thou wilt drain to purpose." It would occupy too much space to quote more from a work interesting not only from its merit as an agricultural treatise, but also from its quaintness. In it we are recommended to use fagots of "willow, alder, elm, or thorns, and lay in the bottom of thy works, or take great pebble stones, or flint stones, and so fill up the bottom of thy trench about fifteen inches high, and then, having covered it all over with earth, and made it even as thy other ground, wait," says the gallant old Cromwellian, "and expect a wonderfull effect through the blessing of God."

In 1727, R. Bradley, Professor of Botany in the University of Cambridge, gives us, in his "Complete Body of Husbandry," some valuable information upon the then state of knowledge upon the question of land drainage. Good practical directions are given for open ditching and "hollow ditching" (covered drains); but his attention appears to have been directed to the drainage of land "which lies wet and is a kind of lake, so that one cannot tread upon it but the water feels like a quag under one's feet." Then follow directions, which resemble those given by Captain Blythe eighty years previously, but whose valuable work appears to have at that time sunk into obscurity. "This improvement (drainage) is chiefly practised in Essex. I have seen it at Navestock, on the forest, at an estate belonging to Aaron Harrington, Esquire, and it is lately brought from that part of the county to the north of Essex, about Wicken-Benant, and near Sir Kane James's; and I doubt not but will be generally used upon all the squally, wet grounds in England when it comes to be known, for it is but a late invention." This author also describes the use of windmills in raising water from a dead level, as commonly seen in Lincolnshire and the fen county; the Persian wheel and the syphon, or, as it is termed, the "crane," is also described and figured as an appliance for lifting water over an embankment; "but," adds the conscientious author, "I cannot take this thought to myself no more than I have done any others that have been communicated to me. I received it from Mr. Harding, a very ingenious founder and master of mechanicks, near Cupid's Stair, over against Summerset House, London" (even professors at Cambridge were not particular in their spelling one hundred and fifty years since). The next great luminary in the history of the art of agricultural drainage was Mr. Joseph Elkington, of Princethorpe, Warwickshire, who commenced farming in 1730. The principles upon which Elkington based his practice were not capable of extensive application, but under certain conditions of soil and subsoil they have been carried out with excellent results. We shall again have occasion to refer to this period when speaking of the practice of drainage. From 1797, the year in which Elkington's system was given to the world by John Johnston, surveyor, in the form of a work, illustrated with numerous diagrams, down to 1823, little attention was bestowed on the subject of land drainage. It was at this time that the late Mr. Smith, of Deanstone, introduced the subject of "thorough draining" to the British public, and gave an impetus to the good work which has sent it rolling onwards ever since. Finally, the use of the cylindrical draining pipe, both by cheapening the material of the underground channel, and reducing the trench to the narrowest possible width, brings us down to the present day, when draining is universally looked upon as the foundation upon which all other agricultural improvements must be based.

FORTIFICATION.—I.

BY AN OFFICER OF THE ROYAL ENGINEERS.

PRELIMINARY REMARKS—DEFINITION OF SCALES—DEFINITION OF TERMS USED IN GEOMETRICAL DRAWING—SLOPES: HOW EXPRESSED—DEFINITION OF THE TERM FORTIFICATION—CONDITIONS THAT, IF POSSIBLE, EVERY FORTIFICATION SHOULD FULFIL—ERRONEOUS IMPRESSIONS HELD WITH REGARD TO THE USES OF FORTIFICATION — SUBJECT DIVIDED INTO TWO BRANCHES—FIELD FORTIFICATION—PERMANENT FORTIFICATION—DEFINITION OF A PARAPET—MATERIALS OF WHICH PARAPETS ARE CONSTRUCTED.

Preliminary Remarks.—The science of Fortification is one so intimately connected with other branches of military art, that it can hardly be rendered interesting or even intelligible to a student who has not previously acquired a certain amount of general military knowledge, sufficient to enable him to realise fully the main principles and conditions under which modern warfare is carried on.

Unless the reader clearly understands the differences existing between the uses and powers of the three great combatant branches of every army—viz., infantry, cavalry, and artillery—it would be useless to attempt to describe to him the defensive arrangements best suited to either of these arms. A certain knowledge of military matters will, therefore, be assumed in these papers, but when technical expressions occur they will be explained.

Most of the operations of fortification are those of practical building or construction, and it is often necessary to express, on the flat surface of the paper, solids of very varied forms; consequently the methods of doing this by means of plans, sections, etc., must be learnt before any real progress can be made.

These methods form the subject of a separate study, termed Geometrical Drawing, and will therefore only be so far explained as may be necessary to enable a reader to understand the diagrams attached to these papers.

In order that the meaning of a drawing of this description may be clearly understood, it is necessary that it should convey not only an idea of the shape and appearance, but also of the actual size of the object it represents.

Definition of Scales.—It is evident that it will often be impossible to make drawings as large as the objects they represent, and it becomes necessary, therefore, that in every important drawing a certain fixed proportion should exist between it and the object represented. This proportion is termed the *scale* of that drawing, and is usually expressed by means of a fraction written on the drawing itself—thus, scale $\frac{1}{120}$, or scale $\frac{1}{480}$, would denote that the objects represented were 120 or 480 times as large as the respective drawings.

The shapes of solids are usually denoted on paper by means of plans, profiles, and elevations.

Definition of Terms used in Geometrical Drawing.—The *plan* gives the length, breadth, and general direction of every part of a work, and is a representation on a horizontal plane of the various lines or edges formed by the intersection of the plane surfaces that bound the solid.

The *trace* of a work is the plan of its guiding or magistral line.

The *section* of a work is the outline of the surface that would be exposed by a plane cutting through the solid in any direction.

The *profile* is a vertical section at right angles to the trace, and shows the true heights and breadths of the object.

The *elevation* is the outline of an object projected on a vertical plane, and gives the heights and general appearance of the various parts.

Slopes: how Expressed.—The degrees of inclination, or steepness of slopes, are expressed by fractions; the slope being considered as the hypothenuse of a right-angled triangle, of which the height is represented by the numerator of the fraction, and the base by the denominator; thus, a slope of

$\frac{1}{1}$ means that the height = base.
$\frac{1}{2}$ „ „ height = $\frac{1}{2}$ base.
$\frac{2}{1}$ „ „ height = double the base.
$\frac{3}{4}$ „ „ height = $\frac{3}{4}$ of the base.

The foregoing elementary definitions being understood, we should next get a clear notion of the principles of the science before becoming involved in its details.

In all ages we find that men, prompted by the instinct of self-preservation, have availed themselves of artificial aids in war, either simply as a means of protection from the missiles of an enemy, or to enable a weaker force to neutralise the advantage that superior numbers or armaments would give to their opponents.

Definition of the term "Fortification." — The various practical operations resorted to are essentially defensive in their nature, and the science which treats of the different ways of applying them to strengthen positions held by troops is termed Fortification.

These operations present an almost infinite variety of detail, for they depend necessarily on the special objects for which they are intended, and the time and means available for their construction.

A knowledge of details is undoubtedly essential in fortification, as in every other practical science; at the same time it will be more important for the student at first to realise the fact that he is not dealing with an abstruse or complicated subject, but merely applying practical common sense to the art of defensive warfare, his object being in all cases to make such arrangements as will oblige the enemy to fight under the most disadvantageous circumstances possible.

Conditions that, if possible, every Fortification should fulfil.—To attain this object thoroughly, every work should fulfil the following conditions:—

1. To afford cover and protection from the enemy's missiles.
2. To enable the defenders to use their weapons with the greatest effect, and with the least exposure to themselves.
3. To render the advance of the assailants as difficult and slow as possible while within the effective range of the works.

These principles are often very difficult to combine, and their application to positions where the circumstances are unfavourable will require the exercise of much thought and ingenuity.

Fortification is necessarily a progressive science, ever changing in some important details as the development of the sister science of Artillery may require; hence it is that we find such a variety in the forms and appearance of the defensive works constructed at different periods and in different countries. A close study of them will show that, however unlike they may appear in some respects, the same principles may be clearly traced through all; not less, perhaps, in the New Zealand "pah" than in the mediæval castle or the modern fortress, if the weapons for which each were intended are borne in mind.

There can be no doubt that, when properly applied and these conditions fulfilled, fortification must ever be of vast assistance to the defence; it can, however, only give a passive assistance, and should not be confounded, as is so frequently the case, with the defence proper, or actual fighting power of the defenders.

Good defensive works undoubtedly enable a small force to fight a much larger one on tolerably equal terms, and, moreover, a less amount of training and organisation is necessary to enable troops to defend fortifications than would be required for manœuvring in the field.

It must, however, be remembered that fortifications without sufficient men and guns to defend them would offer no real obstacle to an enemy, and that unless the offensive powers of the defenders be considerable, they may, in spite of their defences, be defeated by a superior force.

Erroneous Impressions held with Regard to the Uses of Fortification.—Nothing is more common than to hear it argued that because a fortified position is carried by assault, therefore the fortifications were useless, ignoring the fact that if the defenders were unable to repel their assailants when assisted by artificial aid, they would not have had a chance of victory in open fight, and that the loss they have inflicted, as compared with their own, is probably far greater than it otherwise would have been.

Another favourite argument against the use of fortifications is that if they are well placed, and well constructed, the enemy will probably not attack them at all, but will endeavour to pass round, or turn them, as it is termed, and that, therefore, they are useless.

Let us examine this for a moment. It is evident in an attack on any position or territory, there must be a certain definite object in view, and that, in order to obtain this object, there must be certain parts of that position or territory which will be most essential for the assailant to get possession of. Now, if

these vital points are so strengthened by artificial means that, in spite of his superiority of force, the assailant prefers to adopt some other less advantageous scheme, to the certainty of heavy loss and possible defeat in attacking the works, it is clear that these fortifications will have materially assisted in protecting the position or territory, although they themselves were not actually attacked.

Subject divided into Two Branches.—For convenience in instruction, the subject is usually divided into two branches, termed Field and Permanent fortification, although it is by no means desirable that they should be considered as separate studies, for precisely the same principles apply to both; and in permanent fortification we merely see them combined in a complete form, whereas this can only be imperfectly attained in field fortification.

Field Fortification.—This has reference to temporary works constructed during a campaign, within a limited time, and with such unskilled labour and ordinary materials as can be obtained on the spot.

The strength of this class of works varies considerably, from the carefully constructed redoubt, in which all the requisite conditions are fulfilled, to the hasty shelter-trench, or the rough lines of felled timber that so often afforded bullet-proof protection to the troops in the battles of the late American war.

The weak point of all field works, as compared with permanent fortifications, is that, from the fact of their being constructed in a short time, the obstacle they oppose to the advance of the enemy is very much less formidable.

Permanent Fortification.—Permanent fortifications, as the name implies, are constructed of durable materials, and during times of peace, when the choice of materials is unlimited, and when everything is done that skilled labour and elaborate design can accomplish, to render the defence as perfect as possible.

They are intended to secure from immediate capture the arsenals, dockyards, and other points of vital importance in a country liable to attack.

Permanent fortifications are necessarily very costly to construct, and unless destroyed by an enemy will endure for centuries, outliving the men who built them, and the artillery, and even the objects for which they were designed. Hence it is that we so frequently find examples of fortifications that are now obsolete, and we are apt to consider that it was a great mistake ever to have built them, forgetting that they, perhaps, have been of the greatest national importance for many generations, and would be so still, had the art of war remained stationary during that period.

Definition of a Parapet.—To fulfil the conditions of intercepting the projectiles of an enemy, and of enabling the defenders to use their arms with effect, a covering mass of some material is necessary, which must have sufficient strength to resist the enemy's shot, and over or through which the defenders may fire. This mass is called the *parapet* (derived from the Italian words "para petto," *guard the breast*), and its dimensions as regards height are dependent to a great extent on the ordinary stature of men, whilst its thickness must depend on the materials of which it is formed, and the nature of projectile it is intended to resist.

This parapet is usually constructed of earth or sand, as being the material most readily obtained, and most indestructible by an enemy.

Materials of which Parapets are Constructed.—In countries where timber abounds, and where the heavy fire of artillery has not to be provided against, parapets may be constructed of logs of wood placed touching one another, so as to give good bullet-proof cover. These are called stockades, and have the disadvantage of being liable to be burnt, and if struck by shot the splinters of the wood are dangerous.

In some cases where it is impossible to obtain sufficient earth, or where, from the small area available, it is necessary to economise space as much as possible, masonry, and even iron, may be used as materials for parapets. The time required to construct them, and their cost, prevent the employment of these latter materials for any but permanent works. They are chiefly employed in harbour and coast defences, where it frequently happens that the small islands or rocks that are most advantageously situated for the defence of the coast, are too small to admit of a sufficient number of large guns being placed on them, if they are to be surrounded by thick and massive earthen parapets.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

I.—CAPTAIN ANDREW YARRANTON.

BY JAMES GRANT.

ANDREW YARRANTON—a man whose views were in advance of his time by perhaps more than two hundred years—the projector of schemes for improving the inland navigation of England and her agriculture, of plans for docks in London, of a great public bank, and many other brilliant speculations, was born in a humble farmhouse at Larford, in Worcestershire, in the year 1616. When in his boyhood, in 1632, he was bound apprentice to a linendraper, whose services he quitted to become a soldier, when the great Civil War broke out. Being a Presbyterian, he enlisted in the army of the Parliament, where his ability and zeal soon won him promotion, and thus a year or two saw him attain the rank of captain. He must have seen some service against the Royalists, and probably against the Scots, as he records of himself that, "while a soldier, I had sometimes the honour and misfortune to lodge and dislodge an army;" but, modestly, he tells us no more of his fighting career. In 1648 he received the sum of £5,000 from Parliament to reward his "valour and discretion" in frustrating a bold design, conceived by the Royalists, to capture Doylely House, in Herefordshire; but after this we hear little more of Andrew Yarranton in connection with the army, as on the assumption of supreme power by Oliver Cromwell, he quitted it, and, with the money he had won, devoted himself entirely to the cause of trade and industry.

In 1652 he was actively engaged with certain ironworks near Bewdley, in Worcestershire, and with the aid of his wife he established there a linen manufactory, with great success. As regards iron, he early learned to see that it would be the chief means of England's greatness and prosperity, and of her peril then in case of a foreign war. "When the greatest part of the ironworks are asleep," he wrote, "if there should be occasion for great quantities of guns and bullets, and other sorts of iron commodities for a present and unexpected war, and the Sound happen to be locked up, and so prevent iron coming to us, truly we should then be in a fine case!" In the course of his double trade, perceiving the difficulty of communication by roads that were utterly neglected, and to develop the great natural sources of the west of England, he applied himself to a survey of the rivers at his own expense, that he might improve the navigation; and he was thus employed when the Restoration of Charles II. took place.

The journeys of Yarranton from point to point soon excited the surprise and comment of those in local office, even as his success in trade had already aroused their enmity and envy. Then came whispers that the Puritan captain was engaged in a Presbyterian plot, and the 13th of November, 1660, saw him in prison for "refusing to obey the authority" of Lord Windsor, who was lord-lieutenant of Worcestershire. On a false charge of conspiring against the king, he was kept in durance till May, 1662, when he made his escape; and though a party of horse scoured the country, he made his way to London. Ere June came, he was again in prison, and brought before "John Bromfield, George Moore, and Thomas Lee, Esqrs., justices of Surrey," accused of having "broken out of the Marshalsea of Worcester." But he was no more molested, and returned to his favourite schemes for widening and deepening the rivers of the West. His first attempts were on the Salwarp, a small stream, so that Droitwich might be opened to the Severn, and the transport of salt by barges be facilitated; and in gratitude for this, the people of Droitwich gave him a reward of £750, and eight salt vats in Upwich valued at £80 per annum. So lately as 1789, some of the barges used by Yarranton in his navigation were found in the bed of the stream. In 1666 he projected the opening up of the Stour by connecting it with the Trent through a canal, passing by both Stourport and Kidderminster; but money fell short, and more than a hundred years after Yarranton was gone, James Brindley, a kindred spirit, carried out his plans to the letter.

To connect the Thames with the Severn, by means of a canal, was another of Yarranton's far-seeing projects; and by his plans he proposed to cut it at the very place where, as in the preceding case, more than a hundred years after his death, it

was ultimately constructed by others. In his own time, however, this son of industry had the pleasure of opening up the Avon, and was the first to have barges rowed thereon from Stafford to Tewkesbury. Amid all these watery schemes, the improvement of agriculture occupied his attention largely; and perceiving that the land had become exhausted by repeated crops of rye and the tillage of centuries, he urged the adoption of a new system precisely similar to that of the Scottish farmers in the present day—the *rotation* of green and white crops; and with this view he supplied clover-seed in great quantities to the agriculturists of the western counties, where by his advice and measures the land soon became very nearly doubled in value.

Seeing that England was almost without proper harbours or accommodation for merchant shipping, his next, and perhaps his boldest plans, were those of docks for the city of London, where the importers were content to ship and unship their goods by barges in the densely-crowded tideway of the Thames. But poor Yarranton found few supporters, while many laughed at his proposals as Utopian, and they were crushed! While carrying on his ironworks near Bewdley, it had occurred to him that the manufacture of tin-plate would be a valuable addition to English industry, as we were then entirely dependent for that commodity on foreign markets, and all previous attempts to make it at home had completely failed. With this view, the indefatigable Yarranton sailed for Hamburg, and went to Dresden, where then the Duke of Saxony held his court; and from thence to the little town of Au, among the mountains of the district named the Erzebirge or Ore Hills (otherwise known as the Giant Mountains), where at this day more than 500 mines are open and worked. There he learnt that it was a countryman of his own—an aged miner, "a Protestant banished out of England for his religion in Queen Mary's time"—who had first discovered the tin mines of Saxony; and the result was that, at the time of Yarranton's visit, 80,000 men were at work in them, and they had, in gratitude, erected a statue to the memory of the old Cornish refugee. Returning from thence to England with a company of well-skilled workmen, he began to manufacture, in the Forest of Dean, for the home market; and at his works were made many thousand tin plates, which were "pronounced of better quality than those of Saxony;" but an opposition was soon established, for the Crown, harbouring, perhaps, a grudge against the old Cromwellian officer, gave a Mr. William Chamberlain, in 1673, the sole patent "for plating and tinning iron, copper," etc.; so Yarranton's works were abandoned, and those of Chamberlain failed; hence England had to import tin plate from Saxony and elsewhere for more than sixty years afterwards, till a new manufactory, on Yarranton's plan, was started at Capel Hanbury, in Monmouthshire, where it still exists.

Yarranton now proceeded to Holland to inspect the linen factories and the canals of the Dutch, then the most thriving and industrious nation in the world; and, by what he has written, he seemed to have been delighted with the wealth, enterprise, and comfort of Germany and Holland. "For as the honesty of all governments," said he, "so shall be their riches; and as their honour, honesty, and riches are, so will be their strength; and as their honour, honesty, riches, and strength, so will be their trade. These are five sisters that go hand in hand, and must not be parted."

Inspired by a knowledge that the fleets of the Dutch were in every sea, and that their herring-fishers swept all the east coast of England and the shores of the Scottish isles, on his return he at once began a new movement for the development of the wealth and resources of the British fisheries, and made several journeys to Ireland for the same purpose. He afterwards surveyed the Dee, to connect it with the Severn.

The encouragement of the linen manufacture in the central counties of England, where the soil is so well adapted for the cultivation of flax, next occupied his restless attention, as he hoped that the two millions, or thereabouts, sent yearly out of the country for the foreign markets, would be spent at home in the employment of our own people; but as he said himself, "sloth and envy discouraged all my pious endeavours to promote our future happiness."

The first part of his new literary work, "England's Improvements by Land and Sea," appeared at London in 1677; and in its pages, as if gifted with a spirit of prophecy, he foresaw or foretold the future commercial glory of England, his native country, "whose future flourishing is the only reward I ever hope to see to all my labours." The formation of harbours, the extension of the iron, the woollen, and the linen trades; the internal navigation by rivers and canals; the deep-sea fisheries, and the establishment of a public bank based upon the security of freehold land, enabling its notes to pass in transactions equally with bullion; and the scheme of a voluntary register of property, are all broached in his work; and, strangely enough, the year 1862 saw an Act passed in the very spirit of Yarranton's last idea. His project for a Land Bank was revived in 1695, and received the sanction of Parliament; but the Bank of England, then only one year old, petitioned against it, and it was immediately dropped. We know not whether he was then alive.

In 1681 he published the second part of his singular book, "England's Improvement." In limited growths and manufactures, he stated that England and Ireland (to Scotland he made no reference) were the only northern kingdoms remaining unimproved. He again urged the registration of real property; the development of the fisheries; the improvement of the Royal Navy; the fortification of Tangiers (the dowry of Queen Katharine of Braganza), which might thus have become to England then what Gibraltar is now; the reduction of the expense of the Trained Bands, of which England then had eight regiments; the formation of a harbour at Newhaven in Sussex; the development of the vast resources of the Cornish tin mines; and many other projects, all fraught with deep thought and foresight. In the last portion of his book, he suggested that the Cornish tin, if combined with the Roman cinders and iron-stone in the Forest of Dean, would make the best metal in the world. Of this he had some practical experience, having once discovered a vast quantity of Roman cinders near the walls of Worcester, from whence he carried many thousand tons by barges up the Severn "to be melted down into iron with a mixture of the Forest of Dean iron-stone."

After the close of his work was published, he proceeded to Dunkirk (a port then belonging to Britain), for the purpose of making a personal survey thereof; and on returning to London he published a map of the fortress, harbour, and town, with some letter-press remarks, wisely recommending the utter demolition of all the military works, as being more likely to be of service to the French than us. At the close of the same year, 1681, he published his "Full Discovery of the First Presbyterian Sham Plot," referring to the old persecution he had undergone at the Restoration; and after this event his name disappears for ever, nor can any trace be found of where, or when, or how he died, or even where he was interred; but such was the singular and restless career of one whose ideas were far before those of the age in which he lived; and though his writings and even his name are all but forgotten now, in the exhortations to honest industry he sowed good seed in his time; and in Andrew Yarranton we may recognise one of the most earnest pioneers of England's present and future greatness.

PROJECTION.—II.

PROJECTION OF DOOR—TRAP-DOOR AND FRAMING—CUBES AND PRISMS—TO PROJECT A CUBE—SHADE LINES—TO DEVELOP A CUBE.

It will be remembered that in the previous lesson the method of projecting first single lines, and then planes at various angles, was treated of. The present studies are familiar applications of the principles laid down.

Fig. 11 represents a door when the wall is parallel to the vertical plane, the door being at an angle to it. The plan should be drawn first, and the elevation projected from it.

Fig. 12 represents a trap-door and framing, the door being inclined to the horizontal plane, supported in that position by a piece of timber. In this figure the plan of the framing should be drawn first; then its elevation. To this elevation the edge of the trap-door should be added, which should then be projected on to the plan.

In Fig. 13 the entire plan rotated should be drawn first, and the projection obtained by drawing perpendiculars from the angles, and intersecting them by horizontals drawn from the corresponding points in the elevation.

Fig. 14.—Here a plane square is placed with its surface parallel to the horizontal plane, and its edges, *a*, *b*, *c*, *d*, making angles of 45° with the vertical plane. As this plane is supposed to possess little or no thickness, its elevation, when lying flat, is merely the line *a′ d;* the angle *c*, and *b* which lies directly above it, being marked $^{b}_{c}$. If we now raise the square, allowing it to rest on the angle *a*, the extremities of the diagonals, *d*, *c*, and *b*, will travel through parts of circles. Thus, let it be required that the diagonal *a d* shall be parallel to the vertical plane, and inclined to the horizontal at 45°. Draw a perpendicular from *a* to the intersecting line, and thus obtain *a′*. From *a′* draw a line at 45°, and with radius *a′ c* and *a′ d* describe arcs cutting the inclined line in $^{b'}_{c'}$ and *d′;* the extremities of the diagonals are thus transferred from the horizontal to the inclined elevation.

Now the points $^{b}_{c}$ and *d*, in rising higher, will also have moved towards *a* in the plan, in the track indicated by dotted lines; their present position is determined by dropping perpendiculars from $^{b'}_{c'}$ and *d′* to cut the dotted lines; and the points being united by lines, the plan of the square in the required position will be obtained.

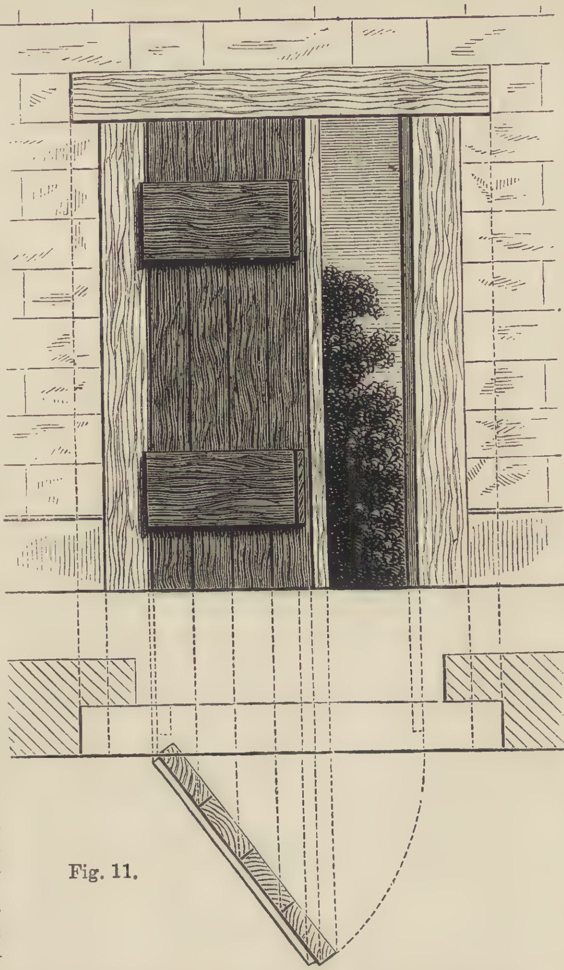


Fig. 11.

Let it now be required to obtain the projection of this square, when, in addition to the diagonal *a d* being inclined at 45° to the horizontal, it is inclined at 60° to the vertical plane; in other words, keeping the square resting on the point *a′*, inclined at its present angle, and rotating it. The plan then will be the same as in Fig. 14, but turned round until *a′ d′* is at 60° to the intersecting line; then perpendiculars raised from each of the angles, intersected by horizontals from the corresponding points in the previous elevation, will give the projection in Fig. 15.

The same plan turned so that *a d* is at right angles to the intersecting line, and worked out as in the last figure, will give the projection of the square when resting on one of its angles, its plane being at 45° to both the planes of projection. It will be seen that the diagonal *c b* has, in all three figures, remained parallel to the *horizontal* plane; but in Fig. 16 it will be observed to be parallel to *both* planes.

The student who has thoroughly mastered the foregoing lessons will have seen that, when he understood the projection of *single lines*, he soon comprehended the delineation of planes, since planes are but forms bounded by lines. It is hoped that the next step, the projection of solids (from the Latin solidus, *compact*), may be divested of some of its apparent difficulties, by the reflection that solids (excepting the sphere and its allied forms, no portions of which are absolute planes) are made up of planes, and that thus, when planes can be projected separately, it will be easy to work out several combined in one object. Thus a cube, or solid square, is formed of six equal squares; and as each of these sides is parallel to the opposite one, the trouble will not be much more than projecting three planes.

CUBES AND PRISMS.

When three or more planes meet at one point, as the corners of a cube, they form a *solid angle.*

A prism is a solid whose opposite ends are equal and similar plane figures, and whose sides, uniting the ends, are parallelograms.

The ends of prisms may be either triangles, squares, or polygons.

A line drawn from the centre of one end of a prism to the centre of the other is called the *axis*.

TO PROJECT A CUBE.

First Position (Fig. 17).—When standing on the horizontal plane, its axis being vertical, and its sides at 45 degrees to the vertical plane.

Let *a b c d* be the plan of the cube, and *e* the plan of the axis. Draw perpendiculars from each of the angles of the plan, and make the height above the intersecting line equal to the side of the plan. Draw the top line, *a d*, which will complete the elevation, the axis being hidden by the edge, *c*.

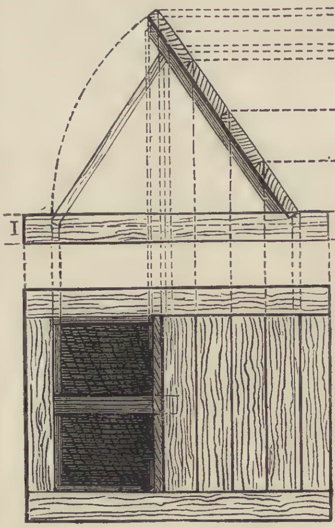


Fig. 12.

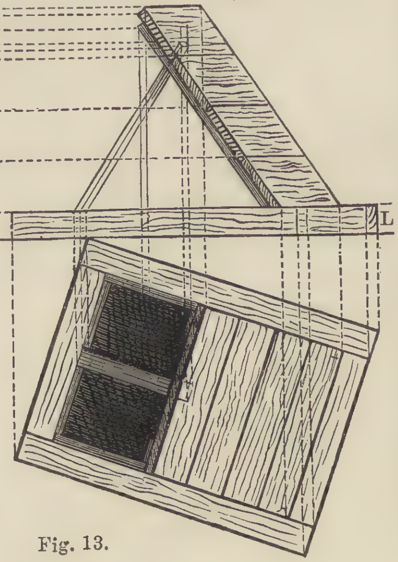


Fig. 13.

Second Position (Fig. 18).—When resting on the solid angle, $a_{,,}$ its axis being inclined at 65° to the horizontal, and parallel to the vertical plane.

As the axis of a prism is *parallel* to *its edges*, it will only be necessary to place the elevation of Fig. 17 so that the edges are at 65°, then the axis will be between the edge *c c* in the front, and *b b* beyond; and as the diagonal, *a d*, which forms the breadth of the base, is at right angles (90°) to the edge, *a a*, the plane of the base will be at 25° to the horizontal plane. Perpendiculars dropped from the angles of this elevation, intersected by horizontals drawn from the corresponding points in the plan of Fig. 17, will give the plan of Fig. 18, or the view obtained by looking down on the elevation, in the direction of the arrow. The axis, *e f*, will now be seen.

The student is urged to letter with the utmost care until he has become accustomed to follow each point through its various changes of position. In Figs. 17, 18, 19, 20, and all subsequent projections of prisms, the points of the base, or lower end, will be marked with the same letters as those of the opposite or upper end, but in smaller characters.

Fig. 19.—When the axis of the cube is at 65° to the horizontal and 30° to the vertical plane.

Place the plan so that the line of the axis, *e f*, is at 30° to the intersecting line. Draw perpendiculars from the solid angles of the plan, and horizontals from the corresponding points in the elevation of Fig. 18. The intersections of these two sets of lines will give the points for the projections.

Shade Lines.—The light has been supposed to come in the direction of the parallel lines on the left of the point *a*. Thus the sides *c d* and *d b* are in shade. This is indicated by the lines on the plan being darker than the others, and all perpendiculars rising from them will be dark also.

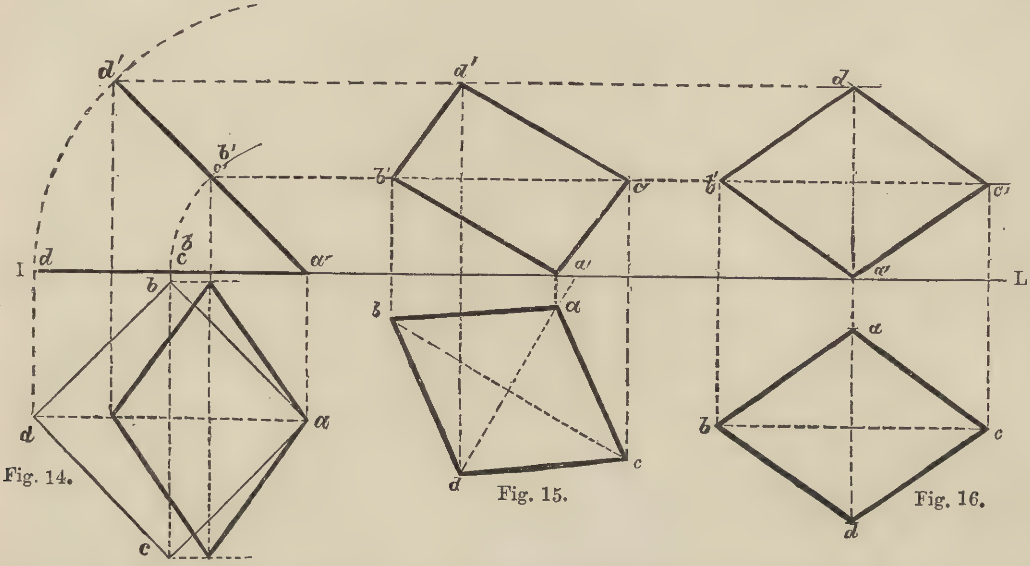


Fig. 14. Fig. 15. Fig. 16.

Development.—The development is formed by the shapes of all the sides of an object being laid down on a flat surface, so that when folded, or connected, a given solid may be either constructed or covered. By *solid* is here meant an object that has the external appearance of solidity. Whether the body be really solid or hollow will be subsequently determined by sections or cuttings.

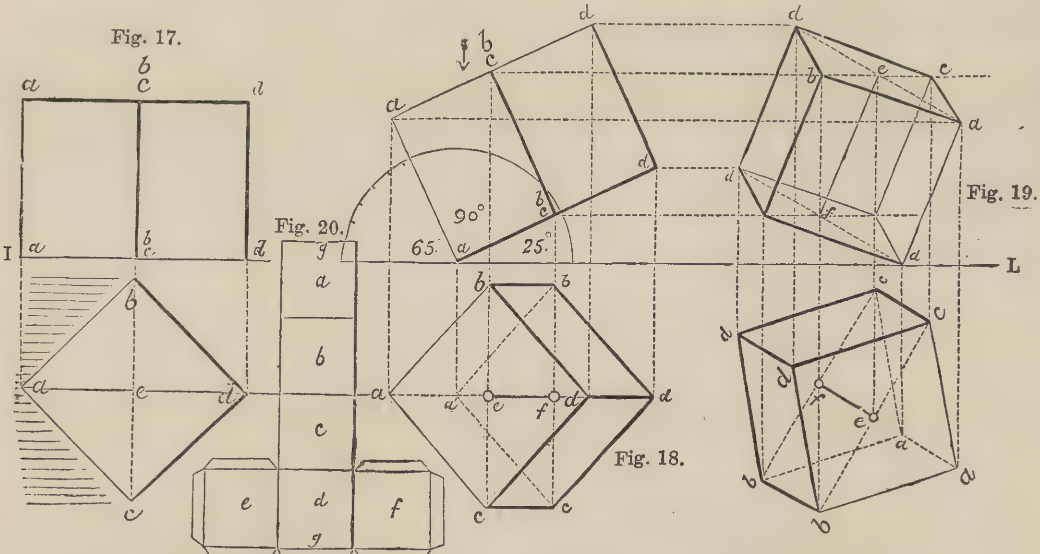


Fig. 17. Fig. 20. Fig. 18. Fig. 19.

To Develop a Cube (Fig. 20).—A cube consists of six square sides. Let *a*, *b*, *c*, *d* be four of these, which, uniting at *g*, *g*, will form the walls, then *e* and *f* will be the top and bottom. A very useful model may be thus formed. The strips left at the edges will be found useful in fastening the sides together. If the model is made of cardboard the lines should be cut half through, and half the thickness of the strips peeled off.

MINERAL COMMERCIAL PRODUCTS.—II.

IRON (*continued*).

Iron pyrites, mundic, the bisulphide of iron (FeS_2), is diffused through rocks of all ages, but the presence of sulphur makes it valueless for the production of iron. It is important, however, both directly as a source of sulphur and sulphuric acid, and indirectly in the immense number of the useful applications of this latter product. Pyrites sometimes contains gold, and it is then called *auriferous pyrites*. Wicklow, Cleveland, Bohemia, Spain, Portugal, and Norway possess very large quantities of this mineral.

Phosphates of iron are worked in Canada, and *silicates* in Switzerland.

The principal processes to which iron ores have to be subjected, in the preparation of iron and steel for manufacturing purposes, are roasting and smelting, refining and puddling, cementation and tempering, varying with the nature of the ores. The roasting process—chiefly necessary for impure ores—gets rid of combustible matter, water, and carbonic acid. The smelting, conducted in large blast furnaces, disengages the metal from the oxygen and earths of the ores, and brings it into the marketable form of cast-iron, in pigs. This is really a carbide of iron, containing a considerable proportion of carbon, with small quantities of some other substances, such as silica and potash, derived either from the ores or the fuel. It is very brittle, and suitable only for castings: and, according to its quality, it is grey iron, which is the best; mottled; and white, which is the worst. Refining, a re-melting of the metal with coke or charcoal, removes some of the carbon and silicon, and produces what is called fine metal. The puddling, which is carried on in a reverberatory furnace, disengages further quantities of these impurities, and makes the iron malleable, prepared in bars or sheets, as required. By cementation, or heating with charcoal, bar-iron is made into blistered steel. From this, by welding, shear-steel is made; and by re-melting and casting, the cheaper cast steel is obtained. Spathose pig-iron can be converted into steel without any intermediate processes. This is done in Styria and other parts of the Continent, and in Borneo. The produce is called natural steel, and is of very fine quality. Ordinary cast-iron, annealed—called "run-steel"—can sometimes be substituted for steel. The tempering of steel, to adapt it, as regards hardness and ductility, for its various purposes, is effected by the processes of re-heating and sudden cooling—the temperature being made to vary with the quality sought to be produced.

The quantity of iron obtained from the principal mining countries is nearly as follows:—

	Tons.		Tons.
Great Britain	4,819,254	Russia	200,000
France (1867)	1,035,000 (and upwards)	Belgium	200,000
		United States	750,000
Prussia and Zollverein	400,000	Spain	80,000
Austria	250,000	Italy	48,000
Sweden and Norway	150,000	Other sources, about	300,000

From these figures it appears that the British produce of iron is more than double that of the rest of the globe.

GOLD.

This noble metal is unaffected either by air or water, and is of great and almost universal use. In civilised countries it forms, as coin, the principal medium of exchange, besides being used in the form of gold-dust for a similar purpose among semi-barbarous nations; and from the richness of its colour and its imperishable nature, it enters very largely into the composition and ornamentation of such articles of utility and luxury as require to be both durable and beautiful. For all these purposes it is peculiarly fitted by its weight (sp. gr. 19·5) and its extraordinary malleability and ductility. In virtue of these latter qualities it can be hammered out into leaves of 282,000 to an inch, and a single grain can be extended into 500 feet of wire. Its natural softness can be corrected by a slight alloy of silver or copper, and in this state it is commonly employed.

Gold is more generally diffused throughout the globe than any other metal except iron, but not in all places in sufficient abundance to render its collection or extraction profitable. It occurs mostly native, being either pure or alloyed with silver, tellurium, and other metals; and often associated with the sulphides of iron and silver.

The modes of occurrence and association of gold are as follow:—

1. In quartz veins of the older rocks, those in the Lower Silurian containing the greatest quantity of gold. Examples are furnished by the auriferous lodes of North Wales.

2. In quartz veins in such Secondary rocks as have been penetrated by certain igneous eruptions, either in the intrusive rock, or in the Secondary strata, and then for a limited distance only beyond the junction of the two rocks. Such an association prevails in California, Central America, and Peru.

3. As auriferous detritus in Secondary and Tertiary deposits, and in the débris and alluvia of rivers, such having been derived from gold-bearing rocks. The *placer* mining of California, Australia, New Zealand, etc., is prosecuted in superficial drift deposits. Gold has been found in streams in Cornwall, Devonshire, Wicklow, and Scotland; and the sands and alluvia of rivers in many parts of the world are washed for this metal.

Our great supplies are drawn from all these sources. The chief are Australia and New Zealand, California and British Columbia, Brazil, Peru, Mexico, and Central America; the Ural, Altaï, and Carpathian Mountains. Gold is also obtained from Thibet, China, Japan, Further India, and Borneo; from the sands of African rivers, especially in Guinea, and from those of the Rhine, Rhone, Danube, and Tagus. Small quantities are procured in mining districts from iron and arsenical pyrites, and other sources, as in Silesia, Saxony, and parts of our own country. The total annual supply is about as follows:—

Australia	£12,000,000	South America	£500,000
New Zealand (1868)	2,504,326	East Indies	500,000
California	13,000,000	Africa	200,000
Russia	3,000,000	Austria	200,000
Mexico and Central America	500,000	Britain	3,000
		Nova Scotia	90,000

PLATINUM.

Platinum ranks with gold in its resistance to the influence of air, moisture, and ordinary acids, and is the heaviest substance known (sp. gr. 21·5). It is white, exceedingly malleable and ductile, and extremely difficult of fusion. On account of its indestructibility it is of great use in the laboratory for crucibles. It is valuable in the arts, and has been employed for coinage by Russia.

Platinum rarely occurs pure. It is principally found alloyed with palladium, rhodium, iridium, iron, gold, or other metals, and generally in alluvial deposits. In the Ural Mountains it has been observed disseminated throughout the whole mass of certain crystalline rocks. The pure metal is got by adding sal-ammoniac to a solution of the alloy in nitro-hydrochloric acid, and washing and heating the compound thus produced. The sources of supply are the Ural Mountains, Brazil, Peru, Spain, Borneo, and Ceylon. The quantity furnished by Russia is 800 cwt.

SILVER.

Silver, like gold, is a noble metal, and is used very extensively for similar purposes. It also needs an alloy to harden it; and being less precious, as well as less weighty (sp. gr. 10·5), is more available for common uses, especially many domestic ones. Its chemical preparations are valuable in photography and surgery. In colour silver is a beautifully brilliant white; it is sonorous, highly malleable and ductile, and perhaps the best conductor of heat and electricity.

This metal occurs pure in some rocks in very fine threads, and large masses of pure silver are occasionally met with in veins. But its supply is principally derived from ores, of which the chief are the *chloride* (AgCl), or *horn-silver*, a greyish crystalline mass, which looks like horn; the *sulphide* or *silver-glance*, and its combinations with the sulphides of antimony and arsenic, which are known as the dark and light red silver ores; and *argentiferous galena* (sulphide of lead), which often contains very considerable quantities.

Silver is obtained from its ores chiefly by roasting, crushing, and amalgamation with mercury. The separation from lead was formerly effected by the superior affinity of lead with oxygen in the process called cupellation, which was in every way costly; and unless the per-centage of silver in the lead was large, it was not separated. A process known as Pattin-

son's is now employed for desilverising lead; it is based upon the discovery that lead crystallises or consolidates at a higher temperature than an alloy of lead and silver. Consequently, if argentiferous lead be kept at the lowest temperature at which the fluid state could be maintained, solid masses of pure lead are gradually formed and removed, the fluid portion remaining being exceedingly rich in silver. Finally, the lead is subjected to the process of cupellation, and the silver separated.

The most abundant supply of silver is yielded by the mines of Mexico, Chili, and Peru, especially those of Pasco. These mines occur in elevated districts, some upwards of 16,000 feet above the sea-level. Considerable supplies are also obtained from other parts of South America, in the Ural and Altaï Mountains, from China, Japan, Cochin-China, Thibet, Asiatic Turkey, Norway and Sweden, the Harz Mountains, Saxony, Hungary, Austria, and the lead districts of the British Isles. The annual quantities are:—

Mexico	£2,420,000	Britain	£180,000
South America	1,650,000	France	60,000
Zollverein	450,000	East Indies (1860)	50,000
Spain	400,000	Norway and Sweden	30,000
Austria	250,000		

MERCURY.

This extraordinary metal—quicksilver, as it is often called—fluid at ordinary temperatures, is the heaviest liquid with which we are acquainted (sp. gr. 13·59). It becomes solid at $-40°$ Fahrenheit, when it is both malleable and ductile. It is used for the extraction of gold and silver; as an amalgam in chemistry, and in the construction of scientific instruments; in manufactures, for silvering mirrors, and for vermilion; and in medicine, for the valuable products calomel and corrosive sublimate, the subchloride and chloride of the metal respectively.

Quicksilver is met with pure in minute globules, but for the purposes of commerce it is obtained from one of its ores—*cinnabar*, a red sulphide of mercury. This ore occurs in the older rocks, but chiefly in those of the Carboniferous system, and the metal is procured from it by a process of distillation. The principal sources of supply are Almaden in Spain, and Idria in Austria, both very rich; Peru, California, Mexico, Australia, China, Japan, Ceylon, Bavaria, Bohemia, Tuscany, and Hungary; and the quantities of mercury annually obtained are about as follows:—

	Pounds.		*Pounds.*
Austria	500,000 to 1,000,000	Peru	324,000
Spain	3,500,000	Germany	21,000
California	1,500,000	Tuscany	55,000

TIN.

This very useful metal is rather a rare one. It is but slightly acted upon by either air or water, is of a white silvery colour, malleable, and easily fused. Its specific gravity is 7·3. Besides being largely used in coating or tinning more oxidable metals, as iron, for instance, in the well-known material called tin-plate, and combining as an alloy to form pewter, bell-metal, type-metal, and solder, it is employed in its chemical combinations for a great variety of purposes in the useful arts. It is found as an oxide, chiefly in the metalliferous veins of the older rocks, also in association with wolfram (a double tungstate of iron and manganese), and, like gold, in alluvial districts, as stream-tin.

By the processes of roasting, smelting, and refining, the stream ores produce the grain tin, which is the most esteemed, and the others the bar or block tin. The most productive districts are Cornwall and Devonshire, the Malayan peninsula and islands, especially Banca and Billiton, to the south of it, and Tenasserim, in the East Indies, China, Saxony, Bohemia, Hungary, Peru, New Granada, Bolivia, Mexico, France, Spain, Siberia, and Australia. Annual supply, about—

	Tons.		*Tons.*
Britain	10,000	Japan	113
China	127	Australia (Victoria)	816
Austria	30	Siam	53
East Indies	5,000		

COPPER.

Copper is a metal of great commercial value, and of very extensive use. It is of a fine red colour, very malleable, ductile, and tenacious, highly sonorous, and a good conductor of heat and electricity. Its specific gravity is 8·96. Independently of its use for coin, sheathing for ships, boilers, and domestic utensils, and of its alloys with gold and silver to harden those metals, copper enters into the composition of brass, bronze, pinchbeck, ormolu, gun-metal, bell-metal, German silver, and the biddery ware of India. It is also largely employed in the production of colours (blue and green), in telegraphy, and in medicine.

It occurs native in fine threads, and occasionally in large masses, the most remarkable of which have been found in Brazil, the district of Lake Superior, and Australia. The principal ores, which occur either in veins or beds, and are most abundant in the primary rocks, are copper pyrites, a sulphide of the metal combined with sulphide of iron; the red oxide (Cu_2O), the black oxide, the green and blue carbonates of copper, and the purple and grey copper ores, the latter associated with iron, antimony, and arsenic. The reduction of the ores is a matter of some difficulty. In Britain it is chiefly carried on in the neighbourhood of Swansea.

Ores of copper are found in Cornwall, Devonshire, Flintshire, Wicklow, and other parts of the British Isles; Chili, South Australia, the Ural Mountains, United States and Canada, near Lakes Superior and Huron; associated with trap rock in Brazil and Cuba; in the copper schists of Mansfeld, in the Harz, Saxony, and other parts of Germany; in Sweden, Tyrol, Hungary, Tuscany, Spain, Persia, India, China, Japan, Algiers, South Africa, and New Zealand. Malachite, a beautiful ore of copper (carbonate), found abundantly in Russia and Australia, can be used as an ornamental stone. The annual supply of copper may be thus stated:—

	Tons.		*Tons.*
Britain	12,000	Sweden	2,000
Chili	21,000	Cape of Good Hope (ore)	4,327
South Australia	6,700	France	3,000
Austria	2,330	United States (Lake Superior)	3,000
Zollverein	2,650		

NOTABLE INVENTIONS AND INVENTORS.

I.—PRINTING.

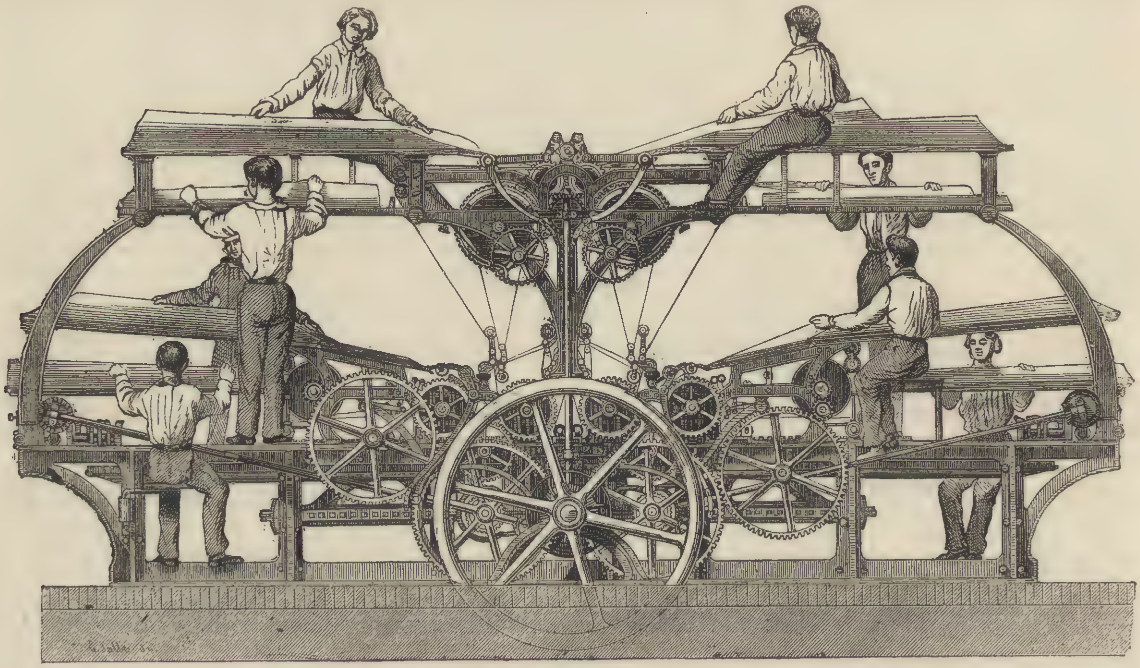
BY JOHN TIMBS.

The origin and history of the "noble craft and mystery" of printing can scarcely be told within a moderate compass, since its principle can be traced in so many forms of producing a copy by pressure, as practised in very remote ages. Seals were impressed upon soft material nearly four thousand years ago, and characters were stamped upon clay in forming the bricks of Babylon. Of this art, Wilkinson and others have brought examples from Egypt, and Rawlinson and Layard from the ruins of the buried cities of Asia; while wooden stamps, with which these inscriptions were impressed, are to be seen in the British Museum. Brass or bronze stamps, with raised characters for printing with colour upon papyrus, linen, or parchment, have also been found; but though the Romans used these stamps, it did not occur to them to engrave whole sentences upon blocks—showing how very nearly we may approach to an important discovery, and yet miss it. The Chinese printing from blocks, at this day, closely resembles the old Roman, and they claim to have practised it before it was known in Europe. Printing from pictures, engraved upon wooden blocks, was accomplished in the thirteenth century; and next, the engravings of the *Biblia Pauperum* (Poor Men's Bible), with the text printed from movable types.

From this period dates the practice of *printing*, in the present sense of the term. Whether wooden movable types were ever employed to print an entire book is very questionable; but no expedient of the kind could have fulfilled the great purposes of this invention, until it was perfected by founding metal types in a matrix or mould, the essential characteristics of printing, as distinguished from other arts which bear some analogy to it. This important advance was made by Gutenberg, whose claim to the invention was disputed in an action at law with his partner in 1439, and evidence produced to show that one of the witnesses had learnt from Gutenberg to "take the pages from the presses, and by removing two screws thoroughly separate them (the letters) from one another, so that no man may know what it is;" thus proving

that separated types were used, as well as some sort of press, as the transfers were no longer taken by a burnisher or roller. Gutenberg died in 1468, and a statue of him by Thorwaldsen was erected at Mayence, by subscription, in 1837. The capture of the city, in 1462, interrupted the labours of Fust and Schoeffer, Gutenberg's partners; they with their work fled into the neighbouring states, and thus spread printing over the whole civilised world, and, within fifteen years, to every town of consideration in Christian Europe. Henceforth, down to the close of the last century, there appears to have been no alteration in the operation; the improvements consisting in the gradual increase of the size and power of the press, together with the great beauty and variety of the types. The press used in Gutenberg's office differed in no essential points from that in use until 1600-20. In woodcuts of Gutenberg's press (1405-1535), the table, with the "forme" of type, remains, and the platen is brought down by a powerful screw, by means of a lever inserted in the spindle, such as might be seen in our time in a London printing-office. It also appears that the matrices and punches used early in the fifteenth century England, remained with him, and succeeded to his business; his works amount to 408. The English printers were for a long time supplied with type from the Continent; but early in the eighteenth century William Caslon established the Caslon Foundry, which still exists. Another eminent founder was John Baskerville, of Birmingham.

We have already referred to the form of presses used to the year 1620. Improvements were from time to time introduced; but they were all superseded early in the present century, when the old wooden press gave way to Earl Stanhope's invention of the iron press which bears his name, and in which the power, instead of being derived from the screw, was obtained from a bent lever that impressed the platen, or iron plate, upon the paper, which is brought down on the surface of the type. The peculiar property of this press is, that when the platen first moves downward its motion is rapid; while, when the power is about to be applied, it is slow, so that the greatest amount of force is concentrated just at the time when it can be of the greatest efficiency. The principle has been followed out by several subsequent inventors. The printing press, however,



MARINONI'S PRINTING MACHINE.

were much in the same form as at the present time. For a long period the printers were their own type-founders; but as the art spread, the casting of letters became a separate business.

To William Caxton and his successor, Wynkyn de Worde—who established for themselves a high reputation, both as printers and letter-founders—we owe the introduction of printing into England. Caxton was born in Kent, 1422-3, and apprenticed to a mercer in London. About 1441 Caxton was sent to Bruges, where he was engaged for thirty-five years in commercial pursuits, and subsequently devoted himself to literature and printing. In 1469 he translated, from French into English, the "Romance of Troy," the demand for which was so great that he could not transcribe copies sufficiently fast, which led Caxton to employ the new invention of printing as a means of multiplying his copies. He derived from Colard Mansion, the first printer at Bruges, his types and his method of working, as shown by Mr. Blades, in his "Life of Caxton," whose first book was printed in 1472, by Mansion himself, at Bruges, and not at Cologne, as hitherto believed. At Westminster he printed the first book in England, "The Game and Playe of Chess," completed in 1476. For fifteen years he continued translating and printing, and died in 1491, about eighty years old. Wynkyn de Worde, who came with Caxton to proved inadequate to render the rate of production equal to the urgent demand; and as early as 1790 Mr. W. Nicholson patented a printing machine, in which "the type, being rubbed or scraped narrower towards the bottom, was fixed upon a cylinder, in order, as it were, to radiate from the centre of it." The cylinder, with its type, was to revolve in gear with another cylinder, covered with soft leather (the impression cylinder), and the type received its ink from another cylinder, to which the inking apparatus was applied; the paper being impressed by passing between the types and impression cylinders. Such was the first printing machine, which was never brought into use, although most of Nicholson's plans were modified and adopted by after constructors. König, a German, conceived nearly the same idea, and constructed for Mr. Walter a printing machine, by which, November 28, 1814, the *Times* newspaper was first printed by machinery driven by steam power, and working 1,100 impressions per hour. In this machine the type was laid upon a flat surface, the impression being given by the type passing under a cylinder of great size. This machine was superseded by that of Applegath and Cowper, in which the novel points were accuracy in the register (one page falling precisely upon the back of the other), the method of *inking* the types, and the comparative perfection of the impression.

König's next improvement was the construction of a "perfecting" machine, which delivered the sheet of paper printed on both sides at the rate of 800 to 900 sheets per hour, equal to 1,600 and 1,800 impressions. Various improvements were made upon the existing machines, increased production and superior work being the result, until Mr. Applegath, in 1827, combined in one leviathan machine four single or two perfecting machines. The product of this machine was 6,000 impressions per hour. The increasing circulation of newspapers, however, the competition among publishers, and the necessity of delaying the "going to press" to the last moment, in order to secure the insertion of the latest intelligence, soon made it evident that something superior even to the great Applegath was required, and the ingenuity of inventors was again taxed. Messrs. Hoe and Co., of New York, introduced their famous "feeders" into London, in 1858, with a result so successful, that the entire system of printing newspapers was revolutionised. The Hoe 8-feeders turned out no less than 20,000 impressions per hour. The "Hoe," being constantly improved, held its own for ten years, and nearly every newspaper of importance in Britain and America used no other. The "Marinoni" machine appeared in 1868. Four of these machines were erected in the office of *Le Petit Journal*, a small paper sold at a sòu, and these produced the extraordinary number of 144,000 copies per hour, being 36,000 for each machine! In the same year the proprietors of the *Echo* introduced the "Marinoni" into London, and that popular evening paper has been hitherto printed by them at the rate of 20,000 perfect copies per hour; the sheet, however, being much larger than *Le Petit Journal*. Four years later (1872) another and more remarkable advance was made. The "Walter Press," so named after the proprietor of the *Times*, made its appearance. It was the joint invention of Mr. Walter and Messrs. Macdonald and Calverley, of the engineering department of the *Times*. This machine differed from its predecessors. The paper is printed from a web of several miles in length, wound on a reel, perfected or printed on both sides, cut and delivered at the other end, at the rate of 17,000 copies per hour!

The illustration shows a 4-feeder "Marinoni" machine, but those in use at the *Echo* office are 6-feeders.

CIVIL ENGINEERING.—I.

By E. G. Bartholomew, C.E., M.S.E.

INTRODUCTION—EARLY HISTORY OF THE SCIENCE.

Civil Engineering is a term so comprehensive as almost to defy a complete and detailed explanation, whilst its importance is only equalled by its comprehensiveness. Its history is even more difficult to deal with, for it runs parallel with almost that of the world itself. Some idea of the scope of this vast science may be formed by stating what are some of the subjects it embraces; for it must not be imagined that the building of bridges, and the formation of canals and railroads, constitutes the whole of the occupation of the civil engineer.

The civil engineer is one who applies the principles of mechanical and physical philosophy to the construction of the machines and public works by which the arts and accommodation of civil life are rendered more efficient, extensive, and secure; and hence Civil Engineering is the term applied to that science which treats of the construction of canals, railroads, roads, bridges, gas and water works, sewage and drainage works, aqueducts, piers, harbours, docks, viaducts, lighthouses, breakwaters, and such like. Each of these subjects involves an acquaintance with detail in their design and carrying out which is by no means apparent on the surface. For instance, in the one subject of *drainage* is involved the arrangement of the dams, sluices, syphons, and machinery of every kind, whether actuated by steam-power, water-power, or the wind, for removing the surplus water, and the canals which by their intersection communicate with every part of the district to be drained. He must be acquainted with all the principles and details of machinery, which is after all but the handmaid of civil engineering, and must be enabled to utilise it to the utmost for facilitating and economising his work. He must also be practically acquainted with the strength of materials, and with those principles of combination by which the greatest amount of strength is gained with the least expenditure of material. He must also have a clear knowledge of brickwork and masonry, and carpenter's work in general. From the foregoing it is evident that the occupation of the civil engineer is far from limited, and that his attainments, if he would excel, must not be few. He must be a man of strong determination to combat with the difficulties he is sure to encounter, and one of ready thought to devise expedients to overcome them. Inasmuch as the civil engineer must be well acquainted with mechanical engineering, and not altogether ignorant even of many points of military engineering, he stands at the head of his profession, and the vastness and variety of his works renders a merely superficial acquaintance with details useless to him; and no man need aspire to any eminence as an engineer who has not climbed the ladder of experience from its lowest round. Some of our best engineers have been men trained in the school of the hardest manual labour, and have risen step by step, gaining experience at each advance, and employing that experience to the development of further achievements; and it is a fact that all our most celebrated engineers have made themselves conspicuous by works essentially their own.

It may, under certain circumstances, be desirable for an engineer to have the assistance of an *architect;* but that engineer who is able himself to proportion his structures to the rules of architecture, and to produce a work as elegant as it is useful, and as useful as it is solid, has an immense advantage over others. Similarly, as many of the public works which the civil engineer is called upon to carry out involve very largely the employment of machinery, both in the course of the work and permanently afterwards, an intimate knowledge of mechanism and mechanics is of the utmost value to him; and certainly no individual is so well qualified to adapt mechanism to the particular function it is intended to perform as the man who undertakes the general design. The architect and the mechanician have each their sphere of usefulness, and very many works are required in which architecture or machinery alone are needed. Such works are not, stricly speaking, in the province of the civil engineer to carry out.

One more remark we would make is that an intimate acquaintance with *geometry* is indispensable for the civil engineer to possess. His operations are very frequently of such a nature as to need great strength, and structural strength necessarily implies that a strain has to be withstood. The engineer must therefore be prepared to meet any strain that may be applied, in the most effective and economical manner. Any unnecessary use of material must be avoided, and therefore, particularly where lightness has to be combined with strength, a clear knowledge of direction of force and strain is an obvious necessity.

That civil engineering is certainly one of the most ancient, if not *the* most ancient of all the sciences, is evident from the magnificent relics which continue, after the lapse of thousands of years, to be the wonder and admiration even of the present age. No doubt the different conditions of society at different periods of the world's history have caused various modes of development of the science of engineering. In the earlier ages war engrossed more attention than the arts of peace, and we might expect to find more attention paid to the arts of war in those days; and hence the works of the early engineers would embrace the defence of their cities by the erection of massive walls and towers, or the construction of engines to demolish them. But although many of the arts of peace may have lain dormant for a while, commerce was not neglected; and we find the Phœnicians, who were the earliest traders on record, more than 1,200 years before Christ, settling upon the coasts of the Mediterranean, building Sidon, Tyre, and other coast-towns, and forming moles and harbours for the protection of their shipping, and for facilitating their loading and unloading. The defence and siege of Tyre (332 B.C.) form most interesting records of early engineering—not, perhaps, strictly *civil*, but nevertheless, a record of ingenious devices to meet emergencies which many a modern engineer would do well to study. When we turn to Egypt we are again met with most remarkable remains of early engineering skill. One of their monarchs, Menes, who lived 2,320 years before Christ, actually diverted the course of the Nile, and, by cutting water-courses and raising embankments, converted the immense marsh which existed upon both sides of the river into the finest agricultural district in the world.

The great lake Mœris, which, according to Herodotus, was

450 miles in circumference, was artificially constructed, and intended as a vast reservoir to receive the overflowing water of the Nile, that it might be subsequently utilised for irrigation. This great work of engineering was accomplished 1385 B.C. The canal which connected the lake with the river still remains. That remarkable work of modern engineering, a work recently completed, the Suez Canal, was accomplished by Ptolemy II. hundreds of years prior to the Christian era. A passing remark is all we can give to the Pyramids—those stupendous works of ancient engineering which, from their construction, must have called into action the highest skill of the Egyptian engineers. These royal sepulchres are not entirely composed of huge blocks of chiselled stone, but are built upon a core or foundation of the original mountain, the native rock itself being excavated to form the burial-chamber; and the manner in which the large masses of stone which form the facing of the rock were cut, carried, and lifted to their respective levels, furnishes an interesting study for the engineer. The great pyramid contains at the present day more than six millions of tons of hewn stone.

The Pharos, or lighthouse of Alexandria, built by that celebrated civil engineer, Sostratus, was considerably higher than St. Paul's Cathedral. It was constructed entirely of stone, and divided into five storeys. But the engineering works of the early Egyptians were not confined to masonry. The people were acquainted with metallurgy and hydraulics. The process of refining gold and silver, and the forging of iron, were practised by them largely. It is not surprising that the science of hydraulics reached an advanced stage in a country so intimately associated with water supply, and the advantages and disadvantages connected with it. To bring the forces of Nature to serve the convenience of man is one of the great aims of the engineer, and this the ancients knew well how to effect. Naturally, Egypt was a marsh; hence their engineers raised dams and banks to restrain the river within bounds. But Egypt altogether without the Nile would be a barren waste, lying as it does under almost a tropical sun, and rarely watered by a shower; hence the Egyptians made lakes and canals to irrigate the land; and to avail themselves of the water when sunk below the level of the soil they devised engines, influenced by wind or water, whereby the lowered waters of the river might be raised, and poured again upon the thirsty soil.

We pass on now to Greece, and here we find engineering directed principally to the erection of temples, and buildings for the celebration of religious rites, chaste and beautiful, but grand and massive; not that the ancient Greeks by any means neglected either commerce or the arts of war. They built magnificent walls to protect their cities from the incursions of man, and capacious harbours to guard their ships from the assaults of Nature. To Hippodamus, a celebrated Greek engineer, the city of Rhodes owed its beauty. Philon and Callicrates were Greek engineers, who lived about 400 B.C. The siege of Rhodes by Demetrius, and its defence by Diognetus and others, form an interesting record of the advance of civil and military engineering in these early times. But probably no individual of the period was so truly an engineer, in the strictest sense of the word, as Archimedes, a man fruitful of resources, and quick of invention, many of whose contrivances are employed to the present day. He was as clever as a mechanician as he was correct as an engineer; and the combination of these two sciences in his person, and the success resulting therefrom, form the best proof we can have of the advantage to be gained in all engineering matters by uniting theory and practice. The stately Parthenon, and other grand Grecian temples, are, it is true, rather monuments of architectural than engineering skill; but the man who could design and erect such massive edifices would require to be an engineer of a high order. To *design* an architrave 21 feet long, 5 feet 8 inches wide, and 6 feet 9 inches deep, might be easy; but who shall estimate the skill requisite to convey a single block of stone of these dimensions to the spot, and elevate it to its site more than 40 feet from the ground—a block containing 803 cubic feet, and weighing at least 50 tons!

But we must not linger amongst the relics of engineering art in Greece. There are greater works to be found in Rome and its neighbourhood, and Vitruvius has left us much information of Roman engineering works, many of which have in part or altogether disappeared.

Conscious of the advantage derived from the selection of a healthy site for their towns, the Romans were very careful to avoid such places as, by their natural position, would render a discharge of sewage a matter either of doubt or difficulty. In this respect the Romans were in advance of ourselves, for we select our position and *afterwards* endeavour how best to drain it, and if the general level prove lower than the means of discharge we are compelled to erect costly machinery to convey it away. The Romans were equally alive to the importance of a good water supply. If, from other causes, they desired to build upon a badly-watered locality, they expended incredible labour, and spared no expense to bring water to their town; and the aqueducts of the Romans are to this day standing monuments of engineering skill. The engineering works of the Romans were not confined to any particular region. Wherever their arms carried conquest, there they displayed the same wonderful ingenuity. The whole of Europe abounds more or less with the remains of the labours of their engineers. Their walls, their gates, their harbours, their temples, bridges, roads, aqueducts, public buildings, the materials they employed, their triumphs over Nature, the height of civilisation they attained to, are all so many proofs of the advanced state of civil engineering science amongst them. Their introduction of the arch in masonry is by itself a memorial to their engineering greatness; for although the existence of the arch in some of the pyramids of Egypt points to an era far before the building of Rome, yet it must be remembered that the Egyptian arches were constructed rather as ornaments, or as covers to sarcophagi, than as the bearers of superincumbent weights, and that therefore the true value of that form was unknown to the Egyptians. But look how profusely the arch is made use of in the amphitheatre of Vespasian, where they stand tier over tier; see the wonderful lightness and immense strength of that enduring monument, so perfect after the lapse of eighteen centuries! What work of modern engineering skill do we find to compare with it?

Modern engineers have followed the plan adopted by the Romans, of forming breakwaters by the immersion of large blocks of stone or concrete, piling them up without regard to order, until they appeared above the water. Of course the base of such a structure is greatly larger than the top, but the prismatic form thus obtained conduces greatly to its stability and strength. Plymouth breakwater is constructed thus, and is only a reproduction of the breakwater at Centocella, now Civita Vecchia.

The Romans eminently excelled in their roads. As a rule these roads were carried forward in a straight line, regardless of all natural obstacles. They are to be found in almost every country of Europe, not excepting our own. Twenty-nine great military roads centered in Rome, and extended thence to the utmost limits of the empire. They were most substantially constructed, and profusely decorated on both sides with temples and other ornamental structures. The Romans are stated to have constructed about 53,000 miles of road. The description of the Appian Way reads almost like a fable. It was 360 miles long, and paved throughout with large blocks of stone, squared and dressed with the chisel, and so intimately united that the interstices between them are scarcely visible. When the roads passed through towns they were built upon vast sewers, which effectually drained their streets.

The bridges built by the Romans have withstood the storms and floods which have carried away many a modern structure. Their aqueducts are marvels of engineering skill, and evidence a perfect knowledge of hydrostatics and hydraulics. The finest of these were the Aqua Claudia, which was fifty miles long, and conveyed water to the capital from Porta Maggiore, and the Anio Novus, sixty miles in length, six miles of which was carried upon arches, some being 100 feet high.

Not only were the Romans exceedingly particular in their choice of sites for their towns and cities; but if necessity compelled them to select a position too contiguous for health to marshy ground, they in the most complete manner removed the evil by an elaborate system of drainage. Rome itself was perfectly drained, most of these subterranean channels remaining to the present day. Tunnels, some of great length, were amongst the engineering works of the ancient Romans. The temples built for their gods, although not equal in massiveness to the temples of the Egyptians, yet far excelled them in magnificence and architectural beauty. Indeed, in all the works

of the Roman engineers we trace a master hand. Centuries have elapsed since they were completed, and although discoveries have since been made, and many great works carried out, we must still yield the palm of merit to the Romans in almost all points of structural and architectural engineering.

Our brief history now passes in silence over several centuries. From the decline of the Roman empire to the middle of the fifteenth century the arts were in a declining state, and little or nothing of an engineering character was undertaken. The first revival of civil engineering in Europe took place in Holland, when the known rich and valuable character of the low-lying land adjoining the sea-coast, and subject to the overflowing of the tides, began to attract attention, and the idea of reclaiming it from the German Ocean was entertained. We merely refer to this now as a matter of history, that the first engineering works of more modern days have been those of drainage, which in the case we have alluded to consisted of the twofold operation of erecting a barrier against the encroachments of the ocean, and then removing the enclosed waters. Indeed, so important was this kind of work, and so valuable the results, that for a long series of years, both in this country and on the neighbouring coasts of Holland, this was the only work of an engineering character attempted. It was owing to the great success which attended the efforts of the Dutch engineers, that some of them, particularly Vermuyden, were invited to England to superintend the drainage of the great fen district in Norfolk, a work which the Romans attempted, but without success.

But we now enter upon a period when we are enabled to give a more connected and detailed account of our own engineering works, premising, however, that as our object in the succeeding chapters upon this subject is to explain the principles and practice of the various branches it may be divided into, we shall only allude to particular works of an engineering kind which have been carried out, in order better to illustrate the subject.

TECHNICAL DRAWING.—II.

TECHNICAL DRAWING BOX—TECHNICAL PENCILS—HINTS ON COLOURING DRAWINGS—LINEAR DRAWING BY MEANS OF INSTRUMENTS.

THE writer has frequently been asked by students, "Which is the *cheapest* box of instruments to get?" whilst others have put to him the question, "Which is the *best* case to buy?" Now, it is not within the province of this work to recommend the instruments of any particular maker, nor to suggest the prices which should be given, as this last depends on the means at the command of the purchaser. But smallness of price is not always real cheapness, and a good article, manufactured by, and bearing the name of, a respectable English house will be found by far the most economical in the end.

Of course the price of a case of drawing implements must depend on what is contained in it. The following articles are indispensable; and these having been obtained as a beginning, single instruments or colours can from time to time be added as occasion may require:—A set of instruments, which should at least comprise a pair of compasses with steel, pencil, and inking leg; a draw-pen; a twelve-inch rule, divided into eighths or tenths on the one side, and twelfths on the other; if possible, a protractor; and certainly a stick of Indian ink. In addition to these, the mechanical draughtsman requires colours; and, proceeding again to name the *smallest* stock he can do with, we advise him to get at starting three only—viz., indigo, lake, and yellow-ochre—from which he will be able to mix most of the tints used in Technical Drawings, according to methods which will be given presently. Of course he will add to the three colours from time to time. Then he will require a small slab—one with three divisions will be found the most useful—and a few brushes with sticks.

As to pencils, the degrees most generally useful are those marked HB and H, the latter of which, being harder than the former, is more adapted for very minute work; but, as a rule, hard pencils are not the best for mechanical drawings which are to be inked, as they are liable to make grooves in the paper, the bottom of which the nib of the drawing-pen does not touch, and hence the edges of the line will be ragged; and further, lines which are drawn with very hard pencils are difficult to rub out. For mechanical drawing, it is best to cut a *flat* point to the pencil; this is done by cutting away the wood, and leaving about an eighth of an inch of lead projecting, which is then to be cut until it is thinned to a flat, broad point like a chisel; the broad side of this point is moved along against the rule, and the line thus drawn will be found to be much finer than one drawn with a round point. The chisel-point is economical in various ways, for it will not break so often, and the point once cut can be rubbed from time to time on a piece of fine glass-paper or a file, or even on the edge of the drawing-paper.

Many of our readers will have experienced the annoyance of a point breaking in the midst of a lesson, just at the moment when following the teacher's illustration line by line. The student is therefore recommended to employ two pencils of the same kind, and to make a point at *each end* of *both* before beginning to work; to keep the spare pencil at his side; as the point he is using becomes blunt or breaks, he turns his pencil; and when the same occurs to the second point, he takes up the spare pencil. He has thus the use of four points, more than which he is not likely to want in one evening.

Once again the student is urged to remember that the mere possession of a case of instruments, however good, will not constitute a draughtsman. The instruments are merely the tools—the mechanical agents through which the mind acts; and it cannot be denied that the more the mind comprehends of the subject to be drawn, the more willing and intelligent servants will the hands become, and the more accurately will they guide the compass or the drawing-pen. Geometrical drawing, then, should be looked upon as a mental exercise more than a merely manual occupation or employment, giving us not only subject for thought and earnest reflection, but enabling us to communicate our plans to others in such a manner that they can understand us and work out our designs better than they could have done from the most eloquent description.

The student will, no doubt, find it difficult at first to draw very fine lines, or to get them to intersect each other exactly as required, especially if he has been engaged in some hard manual occupation during the day; but he will find a little practice will soon overcome this, if he but starts with patience, energy, and the earnest desire to excel.

A FEW PLAIN HINTS ON COLOURING DRAWINGS.

When you are about rubbing up some colour, first see that the slab is not dusty. Then drop some water on it from one of the larger brushes; but on no account dip the cake of colour into the cup or glass of water, which is a most wasteful plan, as it softens the cake, and causes it to crumble off in rubbing.

Rub the paint firmly, but not too heavily, or you will not get the colour smooth. Be careful to hold the cake upright, so as to keep the edge flat.

When you have rubbed as much colour as you think you are likely to want, do not at once put the cake back into its place in the box, but stand it on one of its edges so as to allow it to dry, otherwise it will stick to the box.

Blue, red, and *yellow* are called the three *primary* colours. When *two primaries* are mixed they *produce a secondary colour.* Thus:—

Primaries.		*Secondary.*
Yellow and Red	produce	Orange.
Yellow and Blue	„	Green.
Red and Blue	„	Purple.

When you wish to mix a secondary colour, such as green, from the two primaries blue and yellow, rub the blue in one division of the slab, and the yellow in another, leaving a space between them. Then, with your brush, mix the two colours in this vacant space; but on no account rub either of the cakes in the colour obtained from the other, as this would leave the end soaked in another tint, and when you used it again you would find the colour would be impure. Of course, these remarks apply to the mixing of any two colours.

In order that colour may flow easily, and cover a surface evenly, it is necessary that it should be thin. It is always easy to wash it over again if it is not dark enough, but it is very difficult to wash off the colour if it be too dark.

When you have laid on your colour, do not touch it again whilst wet. If it should require re-touching, let this be done

when it has dried, as you will generally make it worse by stirring about in the wet colour, and will be likely to rub up the surface of the paper.

Wherever it is possible, use a large brush in preference to a smaller one, as you will by this means be the more likely to succeed in getting a flat wash, whilst a small brush might make the tint lie in streaks. Care is, however, necessary in using a large brush, so that you may not pass over the outlines.

To lay a flat wash of colour is of great importance, and to be able to accomplish this some practice is required, in order to obtain which you are recommended to draw several triangles, squares, or other figures, of different sizes. Commence by colouring the smallest, and then work on in order of size, as it is more difficult to spread the wash over a large than a small surface. Let your brush be quite full of thin colour, and, holding it nearly upright, pass it boldly over the upper part of the figure; then gradually bring the colour down, spreading it equally over the whole work as rapidly as you can, so as to prevent, if possible, any one part drying before the whole surface has been covered with colour.

The following is a list of the colours used by most architects to express the various substances:—

Material.	*Colour.*
Brickwork to be executed (in the plans and sections)	Crimson Lake.
Brickwork in Elevations . . .	Crimson Lake mixed with Burnt Sienna or Venetian Red.
The lighter Woods—such as Fir. .	Raw Sienna.
Oak or Teak . .	Vandyke Brown.
Granite . . .	Pale Indian Ink.
Stone generally .	Yellow Ochre, or Pale Sepia.
Concrete Works .	Sepia with dark markings.
Wrought Iron .	Indigo.
Cast Iron . .	Payne's Grey, or Neutral Tint.
Steel . . .	Pale Indigo tinged with Lake.
Brass . . .	Gamboge, or Roman Ochre.
Lead . . .	Pale Indian Ink tinged with Indigo.
Clay or Earth . .	Burnt Umber.
Slate . . .	Indigo and Lake.

Having thus given a few of the elementary principles of drawing and colouring, we will now proceed with our subject, showing the application of these principles, and developing others as the lessons advance.

The principles of foundations being enunciated in the lessons on "Building Construction," it is here proposed to give some studies of the various assemblages of timber employed in such works, in order to afford some useful practice in drawing parallel lines at right angles to each other.

LINEAR DRAWING BY MEANS OF INSTRUMENTS.

Fig. 4 is the plan of a network of timber supporting a platform on which a foundation is to be erected.

Here the transverse sleepers, *a a a a a*, rest directly on a site which, although not soft enough to render piling necessary, is still not sufficiently firm to allow the walls of the structure to be raised without the foundation being extended and equalised.

Fig. 5 is the sectional elevation of the sleepers and wall, *a* being the elevation of the cross-sleepers, which are shaded in the plan.

With thus much information as to the meaning of the subjects before him, the student can now commence work; and as we have often known learners waste half of their evening, and when reproached with idleness, say, "I don't know where to begin," we may here, once for all, lay down the principle, that when the general position of the whole subject on the paper has been decided upon, the sure plan is to *draw first* that which would be *laid down, or built first.* It is also necessary to say that all the drawings in these lessons are to be worked to at least twice the size of these examples.

Well, then, the sleepers, *a a a a a*, would, of course, be laid down first; and therefore these must be drawn first.

Draw the line A B, the front edge of the first cross-sleeper (Fig. 4).

This line is to be drawn with the T-square, holding the butt-end tightly against the left-hand edge of the drawing-board. Do not draw it exactly the length of A B, but longer, and set off the length A B upon it, leaving a little of the indefinite line on each side of A B. The purpose of this will be pointed out to you presently.

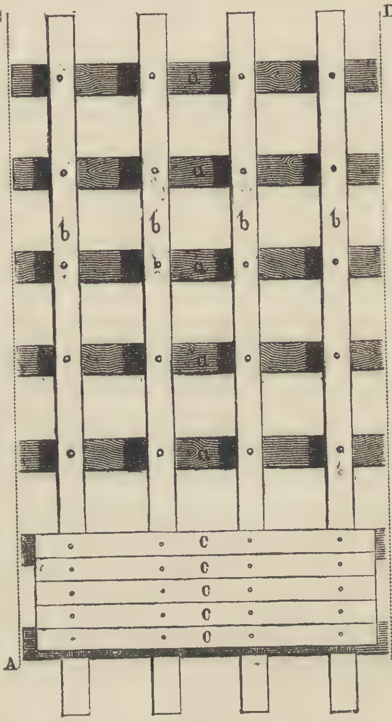


Fig. 4.

Next, keeping your T-square in its place against the edge of your board, move it by its butt-end a trifle lower down, place your set-square against it as shown in the cut, and draw perpendiculars from A and B (as shown in Fig. 4). The immediate purpose of these is to give the ends of all the cross-sleepers; but as they will be wanted for another purpose by-and-by, draw them much higher than they are for the present required: in fact, in all architectural drawing, it is very useful to draw your *pencil* lines *past* their absolute extremities, for reasons which I will explain to you when speaking of inking the drawings.

You will now find it useful to employ two pairs of compasses or dividers. In the one, take the thickness of the sleepers; and in the other, the width of the space between them. From A B set off on the perpendicular, A C, the width of the first one, then a space, then another sleeper, and so on; and draw the lines which give the edges of the sleepers.

It will, of course, be remembered that too hard a pencil should not be used, so that the superfluous lines may be easily rubbed out after inking, and that the pencilling must be done as lightly as possible, so that no more of the grit of the lead than is absolutely necessary may be left on the paper, for this will work up between the nibs of your draw-pen, and cause endless annoyance and difficulty.

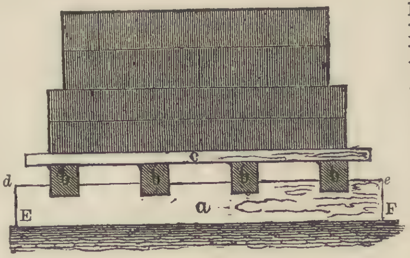


Fig. 5.

With the same width in your compasses, mark off the sizes of the longitudinal sleepers, *b b b b*, which rest on *a a a a a*; and across these again draw the planking, *c c c c c*, the lines forming the ends of these planks to be drawn within the lines A C and B D.

To draw the sectional elevation (Fig. 5), draw the ground-line, E F, and the line above it, *d e*, representing the height of the cross-sleepers, of which *a* is the elevation.

Produce the lines of the longitudinal sleepers in the plan; these will give the sides of their sections in Fig. 5, and across these draw the edges of the planking, *c*, parallel to the lower sleeper. It will be seen that the under sides of these sections are lower than the upper edge of the lower sleeper; this is because they are notched on to it in the manner shown in the lessons on "Building Construction."

On the platform thus constructed draw the section of the pier or wall.

It may be mentioned that the spaces between the sleepers should be well rammed or flushed up to the top of the sleepers—the planking may be then said to rest upon a solid basis—and planks should be spiked to the sleepers with wooden pins.

APPLIED MECHANICS.—I.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

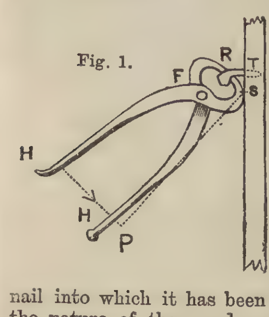
APPLICATIONS OF THE LEVER AND THE SCREW.

It is proposed in this series of lessons to give an account of the practical applications of mechanical principles. The general laws of Mechanics have been already laid down in our "Lessons in Mechanics" in The Popular Educator. Our business is with the application of these laws to practice, and therefore we shall not unfrequently have to refer to them. For example, in the present lesson we shall often assume that the reader is familiar with the different forms of lever and their mechanical properties, of which an account will be found in Lesson VIII. of the series referred to. So also in what we shall have to say of the applications of the screw, we shall suppose that the reader already possesses the knowledge which may be gained by a perusal of Lesson XII. Occasional glances have been given in these lessons of the useful applications of the mechanical powers. It shall be our duty to follow out the useful part to its details. We shall describe and give a practical account of many tools, implements, and machines; we shall select those which are of interest either from the fact that they are of very extensive use, or that they are connected with some important branch of manufacture. We shall occasionally describe a very common tool, and occasionally a colossal machine or structure. It is hoped that an account such as this is designed to be will not only prove of interest to the student of Mechanics, but be of actual service to those who are in any way connected with manufacturing industry.

The lever is susceptible of a vast variety of forms, and it will be useful for the student to practise himself in trying to recognise its presence under its different aspects. In machines of any complexity, which contain a great number of moving parts, many of these parts are levers of one form or another. We shall mention a few of the different cases in which this contrivance is met with.

We begin with one that is very simple and well known—the ordinary pincers. This is shown in Fig. 1, in which the familiar process of pulling out a nail is represented. This tool consists of two levers of the first order; the common fulcrum of both is the pin at F, about which they work. The power is applied at H, by squeezing the ends of the levers together. The load is at R, and consists in the grip with which the nail is held. In the figure the leverage is about sixfold—that is, the jaws grip the nail with six times the force that the ends, H, H, are forced together. The nail is held in the jaws by friction, which increases with the pressure, and consequently, the more powerful the force with which the jaws are pressed together, the more secure is the hold which they have of the nail. Hence we see the principle of the lever of the first order applied in taking hold of the nail, and we shall now recognise it in the subsequent process. When the nail is to be extracted, the side, S, of the jaw is pressed against the surface, and S becomes now the fulcrum. H is pressed down towards the surface by the hand, and this pressure constitutes the power. The load to be overcome is now the tenacity with which the nail resists being withdrawn. This is principally due to the friction of the wood upon the nail into which it has been driven, and of course varies with the nature of the wood and the size of the nail. We shall take one instance. It has been found that a nail called a threepenny brad, which is 1·25 inches long, when hammered to a depth of 0·5 inch into dry Christiana deal, required a force of 58 lb. to extract it. Let us suppose that it is a nail of this size which we have represented in the figure. Now, the action of the hand is twofold—it first squeezes the jaws together, and then, while holding them firmly, presses the whole tool in the direction of the arrow on H H. It is only the latter part of the action of the hand that we are at present concerned with. Let fall the perpendicular S P on H H. Then, by the principle of the bent lever, the power of the hand must be to the resistance of the nail, as the line S T is to the line S P. Now, on the scale on which the figure is drawn, S T is about one-eighth part of S P; hence the power necessary to be applied at H is only 58 ÷ 8, that is, about 7 or 8 lb. There is another advantage gained by the use of this tool, which it is important to notice, as the same case is met with in many different tools and machines. The pincers enable the whole power of the arm to be concentrated on withdrawing the nail. The fingers applied directly would be bruised in fruitless efforts even to stir the nail; but the pincers, by giving a good object to grasp, enable the whole power of the arm to be applied, and then they magnify this power eightfold. No wonder, then, at the remarkable efficiency of this useful tool.

Fig. 1.



Levers are not unfrequently used when there is no mechanical advantage to be gained in the way of power, but where the direction of a force is desired to be changed. In such cases it is sometimes a little difficult to see that the piece is a lever. We must then carefully remember the definition, that a piece capable of turning around a centre, to one point of which the power is applied, while to another point the load is applied, is a lever. A common illustration of this form is shown in Fig. 2, which represents the well-known bell-crank. Bell-wires being stiff and rigid, it would be impossible to change their direction by means of pulleys, and so the beautiful and ingenious contrivance of the bell-crank has been adopted. It consists of a quadrant, usually of brass. It is supported at the centre, F, upon a pin which is firmly fastened to the wall, and about this pin it is free to turn. The power is applied to the circumference of the quadrant at the point P, the direction of its application being perpendicular to the radius F P; this is the point to which the wire is attached by which the pull is given. Now, the effect of the pull on P is to turn the crank round slightly in the direction of the arrow, and this can only be done by raising R; hence at R the wire to transmit the pull is attached. The load is in this case only equal to the power, so there is no gain in that respect; in fact, if anything, there is a slight loss, owing to the friction of the crank about the pin.

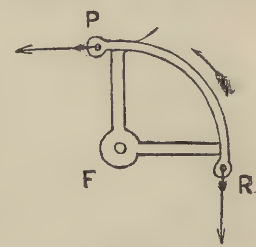


Fig. 2.

A very useful application of the lever of the third order is met with in the common treadle used in turning the foot-lathe. Here the power consists of the pressure of the foot which is applied between the fulcrum at one end, which is the centre about which the treadle moves, and the load at the other end, which is communicated by means of the connecting-rod and crank to the main shaft of the lathe. The power is here diminished, as is always the case in the lever of the third order; but the object aimed at is convenience, and it is found by experience to be easier for the foot to exert a pressure sufficient to move the lathe through a short distance, rather than a less pressure through a longer distance. The real resistance which the lathe has to overcome is not the raising of a weight, but the shearing force necessary to cut off with a tool shavings of wood, ivory, iron, or other work on which the lathe may be engaged. The lathe apparently gives an increase of power, because in turning iron, for instance, the shavings that are cut off are far greater than could have been removed from the work by the direct application of the tool. One reason of this is, that in the latter case only a few muscles of the hand and arm can be employed, while, with the aid of the lathe, all the powerful muscles of the leg can be concentrated on the work.

The screw is a mechanical power of the utmost importance. Its theory has been already fully given in Lesson XII. We shall, then, point out some practical considerations in connection with the use of the instrument.

The efficiency of the screw is largely diminished by friction. In fact, sometimes the power of a screw is found to be only one-fourth of what it would have been had not this force been present. This contrasts the screw with the lever, for in the latter the effect of friction is quite imperceptible. Theory at once in the lever gives the relation between the power and the

load; so does theory in the screw also; but then it must be preceded by and based upon actual experiment.

In order to make this clear we shall fully describe experiments which have been made upon a screw-jack, with a view of determining the relation between the power and the load.

The screw-jack employed is represented in Fig. 3. It consists of a stout tripod of iron, two legs of which are shown in the figure. The top of this, A, is made of brass, and forms the nut of the screw. The screw itself is very carefully turned from a cylinder of wrought iron. Its pitch is two threads to the inch, and its diameter about two inches. The top of the screw is enlarged, as seen at B. This contains two holes, one of which is shown, while through the other the arm B E is passed. This arm is for the purpose of turning round the screw. At C is the crown. This is so arranged that it can turn round on B, so that after it has bitten into the surface which is being pressed upwards it shall cease to revolve, though B is turned round. The object of this is to diminish the great friction which would be experienced by making the top revolve against the surface, and placing the friction instead between the top of the screw and the under surface of the crown, where it can be reduced by having a smooth and well-oiled bearing. Another reason is, that the surface acted on would be torn and injured by the action of the crown. There are slight ridges round the margin in order to make it take firm hold. The bottom of the tripod is also furnished with short projecting points which embed themselves in the surface and prevent the tripod from turning round with the screw.

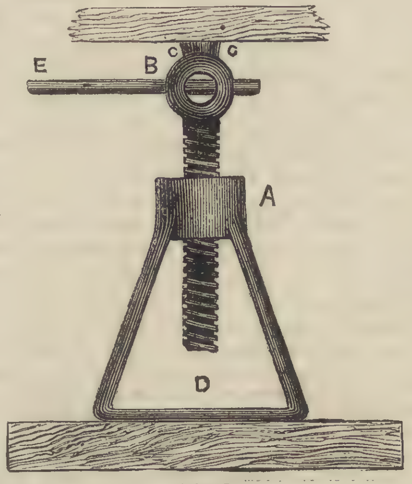


Fig. 3.

The screw-jack used in the experiments now described was one adapted for weights up to two tons. The arm is about 33 inches long. When the arm makes one revolution it moves through a space of

$$2 \times \frac{22}{7} \times 33 = 208 \text{ inches.}$$

But it must perform two revolutions in order to raise the screw 1 inch. Hence the power must have been exerted through a distance of 416 inches to raise the screw 1 inch. According, therefore, to the principles laid down, if there were no friction the mechanical efficiency of this screw should be 416-fold. Let us see how much it is in reality.

A weight of 1,000 pounds is placed upon the screw, and it is found that a power of 8·2 pounds applied to the extremity of the arm is just sufficient to raise it. Hence the real mechanical efficiency is—

$$\frac{1000}{8 \cdot 2} = 122 \text{ lb.}$$

In fact, since $\frac{12200}{416} = 29$, the true mechanical efficiency is only 29 per cent. of what it would have been had there been no friction—less, in fact, than one-third.

It is important to understand this thoroughly, and in general it will be safe to calculate on not getting from a screw more than one-fourth of the power it would yield without friction.

The most useful contrivance by which the different parts of a structure can be united together owes its efficiency to the screw. This is the well-known screw-bolt represented in Fig. 4. Bolts are the stitches by which machines are put together. They owe their utility to several distinct reasons.

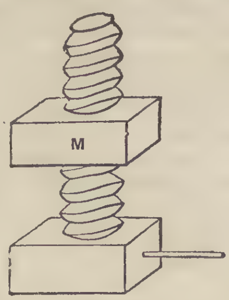


Fig. 4.

1. They enable the parts to be drawn together very forcibly. Thus, suppose a bolt have ten threads to the inch, and that its nut be turned by a wrench, the arm of which is a foot long, the hand must move in one revolution through a circumference of

$$\frac{22}{7} \times 2 \times 12 = 75 \cdot 4 \text{ inches.}$$

Hence, when the nut has been moved one inch, the hand must have moved 754 inches. This would be the mechanical efficiency without friction; with friction it may be assumed about one quarter of this, or 188. Hence, in order that the nut may exert a pressure of one ton in drawing the surfaces together, it is only requisite that the hand exert a pressure of

$$\frac{2240}{188} = 11 \cdot 9 \text{ lb.}$$

Thus, with a force of 12 lb., which can be exerted with little effort, the parts are pulled together by a force of a ton; and with a little exertion a force four or five times this amount is readily produced.

2. The strength with which they hold the parts together is very remarkable. Not only does a bolt bring the parts into intimate contact, but it keeps them there. In fact, if the screw be properly made, and the size of the nut properly proportioned, the bolt may be considered as formed of solid iron when once the nut is screwed home. But wrought iron, when good, requires a force of about twenty tons per square inch of section to tear it asunder; consequently a nut whose diameter is an inch will not be overcome by a force less than about fifteen tons. Though the two means just mentioned are the most important, yet there are several subsidiary reasons why bolts are so extensively used.

3. Their simplicity. A bolt consists only of two parts, for the nut requires no catch to prevent it from slipping back along the screw after it has been brought home. This is due to friction. Without friction every nut would require to be provided with some complicated arrangement to prevent its motion. Bolts connecting parts subject to extreme vibration can generally have their nuts kept tight by the simple process of screwing a second nut down home on the top of the first.

4. Another great practical convenience of bolts is the very different sizes of the work they can grasp. A bolt 12 inches long, and with 2 inches of screw on the end, can bind together any two pieces whose united thickness is a little greater than 10 and a little less than 12 inches. But with the simple addition of washers—which are little iron plates with holes large enough to allow the bolt free passage—a 12-inch bolt can be made to grasp any two pieces whose united thickness is less than one foot.

5. Bolts require very little to be done to the work to which they are applied. All that is necessary is that a hole be bored large enough to admit the bolt. It is not necessary that this hole fit closely; a loose fit acts as well as a tight one.

6. Nor do bolts injure the work when the pressure is applied to them, because by the use of washers of proper size the force can be distributed over a sufficiently large area on the surface of the work, and consequently bruising it can be avoided.

7. Bolts can be very readily applied, removed, or changed, and only a most simple tool—a screw-wrench or spanner—is necessary for the purpose. No skilled workman is required.

8. Bolts being made of wrought iron are everlasting if rust be prevented. They are very cheap, as thousands of tons of iron are annually manufactured into bolts by machinery. They are kept in stock, of all sizes and forms, in shops where they are sold, and they are very portable.

These reasons being considered, we need not wonder at the enormously varied circumstances under which bolts are employed; they load us with a heavy debt of gratitude to that most beautiful of the mechanical powers—the screw.

Little need be said of the common wood-screw. The thread of this screw is sharp, as it has to cut a nut for itself in the wood through which it passes. Its point must first be inserted into a hole, some of its threads then embed themselves slightly in the wood, and thus form the beginning of a nut. When the screwdriver is applied the screw advances, and thus makes its nut more perfect. It may be remarked that a screw should always be at right angles to the grain of the wood, so as to

enable the thread to insinuate itself between the interstices of the fibres. It is obvious that this cannot be done properly if the grain be parallel to the axis of the screw.

We shall conclude this lesson with an account of a common and useful machine, which combines in itself examples both of the lever and the screw. This is the vice, of which, in its ordinary form, a diagram is given in Fig. 5. It consists of two jaws, A B and A′C. A B is continued downwards into what is called the tail, F, which rests upon the ground. The object of the tail is to support the vice when, as is often the case, the work between the jaws at W receives a blow from a hammer. A′ is firmly secured to the bench by means of a strap of iron, T, which passes around it, and is then bolted to the bench at D. Thus the jaw A B is fixed; while the other jaw A′ C is capable of turning around the pin shown at A′. Thus C can either be brought into contact with B, or removed to a considerable distance from it. The object of the vice is to seize the work, W, and hold it very firmly while it is being filed, or drilled, or cut with a chisel, or undergoing some other operation. Of course, it is only for comparatively small pieces of work that such an instrument is used or, indeed, required. The necessary pressure is given to the jaw A′ C by means of a screw, S. In Fig. 6 are shown the pieces of lead which are used for putting on the jaws of the vice when holding work which would be injured by the steel faces of the vice if unprotected.

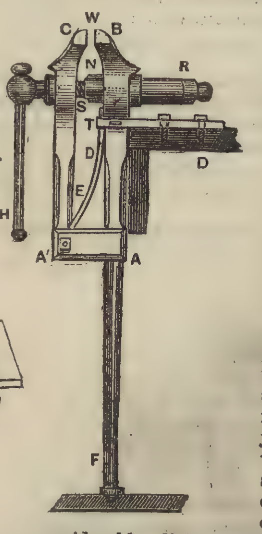


Fig. 5.


Fig. 6.

When the handle, H, is turned so as to move the screw into the nut, the jaw A′ C is brought forcibly towards A B. A′ C is then a lever of the third order, as the fulcrum is at one end, the load at the other, and the power in the middle. The power of the screw is therefore slightly diminished, when applied to the work at C; but as a force of a ton or more can easily be exerted by the screw, it will, even though it loses a third of its amount by the nature of the leverage, exert a tremendous pressure on the work. The surfaces of the jaws are roughened, so that they can take a firm grip of what is between them, and hold it by the friction. At E, a spring acting upon the jaw A′ C is shown. The object of this is to move the jaws asunder when the pressure of the screw is relaxed. The screw and its nut are quite independent of the jaws, and require to be renewed occasionally, as the thread of the nut is apt to wear out by constant use.

There are multitudes of other applications of the screw and lever, and it will be useful for the student to exercise himself in endeavouring to examine them.

ANIMAL COMMERCIAL PRODUCTS.—II.

CARNIVORA.

DIGITIGRADÆ (*continued*).

The *Tiger* (*Felis tigris*) inhabits the Asiatic continent, and is especially abundant in Hindostan. He is nocturnal in his habits, and during the day generally lies asleep in some shady spot, gorged with his last meal. He frequents the neighbourhood of springs and the banks of rivers, where the weaker animals, forced by the scorching heats of the tropics, seek coolness and drink. The skin is a bright tawny yellow, shaded into pure white beneath the body, and beautifully marked with dark bands and stripes. It is used to cover the seats of justice in China, and is also employed for rugs and mats. From 200 to 250 tiger-skins are annually imported into the United Kingdom.

The Leopard (*Felis leopardus*, Cuvier).—This animal is found in Africa and India; it inhabits the deepest recesses of the forest, thus rendering pursuit nearly impossible. Taken usually in traps, it is also hunted with dogs, until, being an expert climber, it takes refuge in a tree, and when the hunters come up it is easily shot. The skin is a tawny yellow, the lower parts white, and covered all over with dark spots, which vary in size and form. It is worn as a mantle by the Hungarian nobles who form the royal body-guard of Austria; it is also used as a saddle-cloth in some of our cavalry regiments, as a mark of rank amongst the officers. About 200 leopard-skins are sent annually to the English fur market.

The Jaguar, or *American Panther* (*Felis onca*, Linnæus).—A native of the warm parts of America, especially Paraguay and the Brazils. Next to the tiger, the strongest species of the genus; also an expert climber. The skin is beautifully marked with deep chocolate-brown spots upon a rich yellowish ground. From 300 to 400 skins of this animal are annually imported, and used as rugs, or for ornamental purposes.

The Puma, or *American Lion* (*Felis concolor*, L.).—Extensively distributed throughout the Southern American continent, found also in the warmer parts of North America. More frequently met with in grassy plains and marshy meadow-lands bordering rivers than in the forest. This animal lives upon deer, hogs, and sheep, to which it is very destructive; for it is not satisfied with the simple seizure of prey, but, meeting with a herd of animals, will kill as many as possible, sucking only a portion of the blood from each. The fur of the puma is thick, close, and reddish-brown in colour, changing on the belly to a pale reddish-white. The skin, when imported, is used for carriage wrappers.

The Canadian Lynx (*Felis Canadensis*, Geoffroy).—This is a timid creature, common in the wooded districts of Canada as far north as 66°, incapable of attacking the larger quadrupeds, but well armed for the capture of the American hare, on which it principally feeds. It makes a poor fight when attacked by the hunter, spits and sets up its hair like an angry cat, but is easily destroyed by a blow on the back with a slender stick. From 15,000 to 20,000 lynx-skins are annually sent over to this country by the Hudson's Bay Company.

The Common Cat (*Felis domesticus*, L.).—In Holland the cat is bred for its fur, being fed on fish, and carefully tended until it arrives at perfection. We import annually 20,000 cat-skins, and the English fur-market also receives a considerable quantity from home. The cat's skin makes an excellent rubber for electrical machinery, and is also used for sleigh coverings, railway rugs, etc.

The Family *Canidæ* (Latin, *canis*, a dog) forms the next group of Digitigrade Carnivora, and includes dogs, wolves, and foxes. The different varieties of dog are supposed by some naturalists to have been derived from the wolf. The common dog (*Canis familiaris*, L.) is distinguished from the wolf and jackal by its recurved tail; but the species vary very much in size, form, and the colour and quality of hair. In most collections of fur a few dog-skins will be found, although there is no regular trade in them.

The *Wolf* (*Canis lupus*, L.) has a valuable skin. This animal, once indigenous to this country, but now exterminated, still lingers in the forests of Northern and Southern Europe, and is particularly abundant in Russia, North America, and the northern parts of Asia. From 9,000 to 10,000 wolf-skins are annually imported from Europe, the United States, and British North America. They are serviceable for the linings of coats and cloaks, for sleigh coverings, and wherever additional warmth is desirable.

The Red Fox (*Vulpes fulvus*).—It is not the common European fox that is found in the furriers' shops of this country, but different varieties of the American (equally well known for its cunning and mischievous attacks on the poultry-yard). The fox is easily distinguished by its long, sharp nose and bushy tail. Foxes have been formed by zoologists into a distinct group amongst the *Canidæ*, or dogs, on the ground that the pupil of their eye is vertical, whilst in the dog it is circular. The tail of the fox is longer and more bushy, its head broader and more pointed in the muzzle, and its gait and attitude crouching. The red fox of America is ferruginous in colour, and strongly resembles the fox of Europe. About 8,000 skins are annually imported into England, most of them to be re-exported, chiefly into the markets of Turkey.

The Cross Fox (*Vulpes decussatus*).—This is probably only a

variety of the red fox. It is distinguished by a black cross on the neck and shoulders, and is a South American animal. Its skin is valuable, selling for £4 or £5.

The Arctic Fox (*Vulpes lagopus*).—This animal is very common within the Arctic circle, and exhibits in a remarkable manner that mutation of colour which polar animals undergo with the change of the seasons. In winter it is a pure white; in summer a dorsal line of a darker colour is observable, with transverse stripes upon the shoulders. This circumstance has led to its being mistaken for the cross fox. Late in autumn these animals collect in vast numbers on the shores of Hudson's Bay, and migrate southward, returning early in the following spring along the sea-coast to the northward. The southern limit of their migrations in North America is 50° north latitude. The Arctic fox is very cleanly in its habits, very unsuspicious, and easily snared. There is a dark variety known as the sooty or blue fox (*Vulpes fuliginosus*). Both the blue and the white otter, and wolverine. These animals, from their peculiar appearance and habits, have been called vermiform quadrupeds. They are distinguished by the length and slenderness of their bodies, which enable them to wind like worms into very small openings and crevices, whither they easily follow the smaller mammalia and birds on which they prey. Several of them, as the polecat, emit a very offensive odour; nevertheless, they yield the most costly and highly-prized of our furs.

The Ermine (*Mustela erminea*).—This, the most interesting species of the weasel family, resembles the common English weasel, and inhabits Siberia, Russia, Norway, and Sweden. In winter it is clothed by Nature with a fur as white as the snow which then covers the ground, and is thus rendered invisible to its numerous enemies; in summer its garb changes to a dingy brown.

The white fur of the ermine is highly esteemed. It is the

THE RUSSIAN SABLE (MUSTELA ZIBELLINA).

skins are imported in considerable quantities, but they do not fetch so high a price in the English market as the skins of the red fox.

The Black or Silver Fox (*Vulpes argentatus*).—This species is distinguished from the others by its intensely black fur, which is intermingled with silvery hairs, and has a white spot at the end of the tail. It is a native of the northern parts of the American continent. "An unusually fine skin of one of these animals has been sold in London for £100. The imperial pelisse of the Emperor of Russia, made of the black necks of the silver fox (exhibited at Hyde Park, in 1851), was valued at £3,500."

The Cossack Fox (*Vulpes Cossac*).—This fox inhabits the vast plains of Tartary. Its skin, which is of a clear ferruginous-yellow colour, is much prized in Russia and Turkey. Not fewer than from 40,000 to 50,000 of these animals are annually taken and sold.

The Family *Mustelidæ* (Latin, *mustela*, a weasel) forms the last group of Digitigrade Carnivora whose skins supply our fur markets. This family includes the sable, polecat, weasel, royal fur of England, and of the sovereigns and emperors of Europe. The Pope and his cardinals have their ecclesiastical robes adorned with capes and trimmings of ermine, according to their rank. The tail alone of the ermine is jet-black, and this is inserted at intervals into the prepared furs as an ornament.

"In England there is now no restriction on the wearing of this fur, but in the reign of Edward III. it was forbidden to all but the royal family, and a similar prohibition still exists in Austria. There is, however, a characteristic distinction made in the mode of ornamenting the fur employed on state occasions, according as it is worn by the sovereign, or by peers, peeresses, judges, etc. The sovereign and royal family can alone wear ermine trimmings in which the fur is spotted all over with black—a spot in about every square inch of the fur. These spots are not formed of the tail of the ermine, but of the paws of the black Astracan lamb. The crown is also adorned with a band of ermine with a single row of spots. Peeresses wear capes of ermine, in which the spots are arranged in rows, the number of rows denoting their degrees

of rank. Peers wear robes of scarlet cloth, trimmed with pure white ermine without any spots. But the number of rows, or bars of pure ermine, in this case also denotes the rank. The robes of judges are also scarlet and pure white ermine."* The number of ermine skins annually imported is upwards of 100,000, and of these very few are exported. The fur of the ermine is manufactured into ladies' muffs, tippets, trimmings, and linings.

The Russian Sable (*Mustela Zibellina*).—This is the next fur to ermine in value and in general use. The animal which yields it lives in the wilds of Siberia, and is hunted in the depths of winter, when its fur is most valuable. The fur is brown, with some grey spots on the head. The darkest in colour are the best. The skins are small, but they are sold at prices varying from three to ten guineas. Only about 2,000 of these valuable furs are received in England, because so much prized in Russia, where about 25,000 skins are annually collected.

This fur is usually manufactured into linings, sometimes valued as high as 1,000 guineas. The Lord Mayor, aldermen, and sheriffs of the City of London have their robes and gowns lined with Russian sable, according to their respective ranks.

MUSTELA ERMINEA AND MUSTELA VULGARIS IN WINTER.

The tails of sables are used in the manufacture of artists' pencils and brushes.

The Minx (*Mustela vison*).—This animal is a native of North America, and its skin comes to us principally through the Hudson's Bay Company. In the month of March this Company holds annually, in London, a public fur sale, which attracts great numbers of foreigners. Through them the furs destined for the Continent find their way to Leipsic, whence they are distributed throughout Europe. The fur of the minx resembles the sable in colour, but is considerably shorter and more glossy. It is much used for ladies' wear, and is made into victorines, cloaks, muffs, etc. In a single year, the number of skins of this little animal received in this country have amounted to a quarter of a million. Their price varies from ten to fifteen shillings a-piece. When this skin is of a silver-grey colour, it is additionally valuable. A muff made of six of such skins is worth twenty-five guineas.

The American Sable (*Mustela leucopus*).—The fur of this animal varies from a tawny colour to a deep black. The animal itself is known by its white feet. The fur is much worn in England, and is made into cuffs, muffs, and boas. In 1856, 206,000 marten skins were imported. Of these the greater number belonged to this species.

The *Polecat* (*Mustela putorius*) is common throughout Europe. It is very destructive in the poultry-yard, and very courageous. Its flexibility is so great, that when seized improperly by a terrier, or not griped in the right place, it will turn and fasten on the dog, so as to prevent further attack. This animal has a soft black fur, with a rich yellow ground. The natural odour of the fur is unpleasant, but processes have recently been adopted which effect its removal: 150,000 to 200,000 of these skins are annually sold in the London fur markets. The finest are obtained in Scotland. More than 25,000 are exported yearly from this country to America, where the fur is much sought after.

The *Pine Marten* (*Mustela abietum*, Ray) is found abundantly in the forests of Northern Europe and America. It shuns the habitations of man, and preys on birds and the smaller animals —mice and hares. When its retreat is cut off, it shows its teeth, sets up its hair, arches its back, and hisses like a cat. Upwards of 100,000 pine marten skins are annually imported into England from the territories of the Hudson's Bay Company and Canada.

The Beech Marten (*Mustela Foina*).—This animal has a white throat, and is thus distinguished from the pine marten, the throat of which is yellow. It is found in woods and forests in Northern Europe, but nearer the habitations of man than the pine marten. It is imported in considerable quantities from the north of Europe, and its fur is dyed to imitate sable.

The Stone Marten (*Mustela saxorum*).—This animal is distributed throughout Europe. Its under fur is bluish-white, with the top hairs a dark brown; its throat a pure white, by which it is generally distinguished. The French excel in the art of dyeing this fur, and for that reason it is frequently sold under the name of French sable.

The Tartar Sable (*Mustela Siberica*).—This little animal is caught in the northern parts of Russia and Siberia. The fur is bright yellow, the colour being remarkably uniform all over the body. The skin is used both in its natural state and dyed; the tail is employed for artists' pencils. In 1856 we imported as many as 70,000 skins of this animal.

The Woodshock, or *Pekan* (*Mustela Canadensis*).—The pekan inhabits North America, and is also called Hudson's Bay Sable. As the natural colour of this skin is much lighter than the prevailing taste, it is dyed of a darker hue. Thus treated, it is scarcely inferior to the Russian sable, which it is intended to imitate. We import annually about 18,000 of these skins.

* "Cyclopædia of Useful Arts." By Charles Tomlinson. Vol. I., p. 729.

BUILDING CONSTRUCTION.—II.

SCALES.

It has already been said that block plans, elevations, etc., are drawings which show the whole property, building, or machine, and that working drawings are executed of a larger, in fact, sometimes of the real size of each portion, so as to guide the workman.

Now it will be clearly understood that although the drawing may be much smaller than the object it represents, it must, for any useful purpose, have all its parts in proper proportion; and not only this, but the drawing must be made in such a manner that it may at once be evident what the true size would be. This is called the "scale."

TO CONSTRUCT A PLAIN SCALE.

Let it be required to construct a scale of 1 inch to the foot. This has been taken for the first example, owing to its great simplicity; for it will be at once understood that a 12-*inch* rule will represent 12 *feet*, and therefore the drawing executed on this scale will be *one-twelfth* ($\frac{1}{12}$) of the real size. This is called the *representative* fraction. Draw a line of any length, and mark on it several inches. Mark the left-hand end of the line 0, the first space 1, and so on. This, however, only gives *feet*; it is necessary, therefore, to divide the inches into twelfths,* and then each twelfth will represent an *inch* of the real measurement. It will be obvious that the same principle will apply to the construction of scales, whatever the representative fraction may be; thus—

TO CONSTRUCT A SCALE OF $\frac{1}{120}$,

that is, one of *one-tenth* of an inch to the foot; because there are 10 tenths in an inch, and 12 inches in a foot. Draw a line of indefinite length, and mark off on it any number of tenths of an inch; these will represent feet. It is not necessary to figure every division, nor to carry them beyond 10 feet in single feet; after that they may be marked in 5-feet lengths.

Of course, on such a small scale separate inches would not be required; it is only necessary, therefore, to divide one of the tenths into four parts, each of which will represent *three* inches. The detail would then be drawn on a larger scale, as already explained.

GENERAL PRINCIPLES OF BUILDING CONSTRUCTION.

The term *construction*, as applied in practical art, is generally understood to mean *fabrication* rather than *form*, its object being the adaptation of such materials as are most fitted for the purpose intended, and the art of the constructor being devoted to combining them so as to ensure permanency and stability.

If an upright wall be properly constructed upon a sufficient foundation, the combined mass will retain its position, and bear pressure in the *direction* of *gravity* to any extent that the ground on which it stands and the component materials of the wall can sustain. The aim of the constructor then must be, first, to secure a firm basis on which the fabric is to rest, and secondly, so to dispose his structure, and so to combine all the parts, that the whole pressure may act in the required direction: for instance, when a building is to be roofed, the rafters, if butting merely on the top of the walls and meeting at the ridge, would of course be liable to press the wall outward. The constructor, therefore, designs a "truss" in a manner best adapted to the particular case. A truss consists, in the first place, of a tie-beam, which is a strong piece of timber. The lower ends of the rafters are mortised into this, and their upper ends are inserted into the top of an upright piece called a "king-post," which, acting as a keystone of an arch, keeps the rafters in their places; whilst their lower ends, being inserted into the tie-beam, *cannot* spread outward. A firm triangular assemblage of timbers is thus formed, and when this is raised to its place on the walls, there is not any pressure *outward*, the entire weight bearing *vertically*, that is, in the direction in which the wall is best calculated to bear it; and should the design of the building not permit of the introduction of the tie-beam, the constructor applies buttresses outside the walls, to enable them to resist the thrust caused by the weight of the roof. The numerous ways in which scientific construction is practically applied in building, will be exemplified according to the requirements of the different materials treated of in the following pages; and we will proceed, in the first place, to speak of

FOUNDATIONS.

By the term *foundation* is meant—

1. The surface or bed of earth on which a building rests; and

2. The manner in which the lower portions of the building are constructed so as to afford the best possible bearing for the superstructure.

Foundations are spoken of as (1) *natural* and (2) *artificial*.

Although both these terms seem self-explanatory, it is still deemed advisable to refer briefly to their exact signification in accordance with the principle adopted in this series of papers; viz., not to assume any previous knowledge; and although this plan may be open to the objection that information may be supplied which many students have already acquired, yet this is by far safer than that any one who may be totally unlearned on the subject should seek information in these pages and be disappointed.

A *natural* foundation, then, is such as will be found where the site is underlaid by a solid rock, or any kind of incompressible, resisting substances, free from water. Of course this must depend entirely on the locality; and it must be borne in mind that it is not so important that the ground should be perfectly rocky and hard, as that it should be compact and of similar consistence throughout; it is not so necessary that it should be absolutely *unyielding* as that it should yield *equally* throughout.

Artificial foundations are such as are *constructed* so as to render the ground, which is too soft to bear the building, fitted for the purpose required. Of course the means adopted must depend on the situation, the nature of the soil, the character or purpose of the building, etc.; and some of the methods mostly used will be here described and illustrated.

Bad foundations have been the cause of the ruin of many modern buildings. This has arisen from the costly nature of the work in making good the site, when the soil is not naturally suitable. But it is clear that the saving of the first expense is an unwise economy, as the entire stability of the superstructure necessarily depends on the firmness of the foundation.

The first process in connection with laying the foundations is sinking the trenches in which the bases of the walls, etc., are to rest, and in digging out the hollows for cellars, etc. This is called the *excavation*.

If the surface be found to be perfectly rocky, or to consist of a gravelly soil embedded with stone, it becomes a good natural foundation when it has been reduced to a level. If the soil prove generally firm, the looser parts, if not very deep, may be dug up until a solid bed be reached, and the hollow may then be filled up with broken stones and concrete; if the soil be not very loose, it may be made good by ramming into it large stones, closely packed together, or dry brick rubbish widely spread; but if the ground be very bad, it must be piled and planked, or covered with a bed of concrete, according to the circumstances.

In a building to be erected on a slanting site, the foundation must rise with the inclination of the ground, which must be "benched out"—that is, cut into a series of broad steps; this will ensure a firm bed for the courses, and prevent them from sliding, as they would be likely to do if built on an inclined plane.

When a good hard foundation is easily accessible, as solid gravel, chalk, or rock, we have nothing to do but to excavate the surface mould to the sound bottom, and build at once, first putting in the "footings," which are one or more courses forming a sort of steps, each projecting a little beyond the other. These footings will be referred to and illustrated further on. On hard ground, one course of masonry, about half as wide again as the wall, is ample, but of course this must depend on the discretion of the architect. The rule, however, which must always guide the builder, is that the broader the base the safer the construction, and therefore the softer the ground, the wider it will be necessary to spread the foundation; and thus on softer ground, in many cases, footings have been employed

* To divide a line into any number of equal parts, see "Lessons on Practical Geometry," page 64.

extending not only double the width of the wall, but even more.

But the invention, or rather the re-introduction of concrete, has altered much of the system formerly adopted. When the ground is a deep clay, the building material, be it what it may, should go so deep as not to be influenced by changes of temperature or the rising or falling of springs, as the alternate shrinking or swelling of the ground must affect the stability of the building. It has been satisfactorily proved that in this country frost seldom penetrates beyond a foot into the ground, but in clayey soils, cracks and fissures, caused by the drying of the ground, frequently extend to the depth of two or three feet. Under such circumstances the bases of the foundation should be below such level. If the ground be springy, it should be drained, if possible; if not, a foundation must be laid with concrete as low as the lowest level of the water, or, if very deep and boggy, *piles* must be used. The plan of building on sleepers or planking has now been almost entirely discarded; for experience has shown that timber, where exposed to alternations of wet and dry, soon rots, and is liable to be crushed, thus allowing the walls to sink. Where the ground is wet at one time and dry at another, the best timber soon decays, and therefore piles used in supporting buildings should, where possible, be so placed as not to be liable to such alternations.

The use of concrete, except under very peculiar circumstances, has entirely superseded all other substances used in artificial or semi-artificial foundations. Concrete may be defined as a sort of rough masonry, composed of broken pieces of stone or gravel, not laid by hand, but thrown at random into the trenches, cemented together with lime in various ways, and thoroughly mixed with it before it is thrown in.

In England, the lime is generally ground, and mixed, when hot, with the stones. In France, however, the lime is first made into a paste, and the mixture is called *béton*. *Béton* has been much used in foundations of breakwaters, bridges, etc., as it has the property of hardening under water. The use of this composition is of very ancient date, and many examples of its use by the Romans still remain to us on the coast of Italy; it is supposed to be the "Signinum opus" mentioned by Vitruvius.* It was in very common use in the Middle Ages, walls, and even arches, having been frequently made of it. Smeaton† states that he was induced to use it from his observation of the ruins of Corfe Castle,‡ in Dorsetshire.

Dance, the architect of Newgate Prison, employed a sort of concrete in rebuilding that structure in 1770-78. The site of part of the new building was a deep bog, and it was rendered available by shooting a quantity of broken bricks into the holes, mixed with occasional loads of mortar, in proportion of 4 to 1, and suffering them to find their bed.

* Vitruvius, Marcus, a celebrated Roman architect, who was born about 80 B.C. He received a liberal education, and pursued those studies which were calculated to fit him for the profession of an engineer and architect, and was engaged in the Roman army as superintendent of military engines. He wrote a work called "De Architectura," in ten books, treating of the different branches of architecture and civil engineering.

† Smeaton, John, an eminent civil engineer, was born at Austhorpe, near Leeds, in 1724, and early showed a bent towards mechanical pursuits. In 1755, an event occurred which was to afford him the opportunity of reaching the very summit of his profession. The second wooden lighthouse which had been erected on Eddystone rock (which is one of a group of rocks daily submerged by the tide, situated in the English Channel, nine miles off the Cornish coast) was destroyed by fire. The speedy re-erection of another beacon was of the utmost importance, and the execution of the work was entrusted to Smeaton. The new lighthouse was built of stone. The cutting of the rock for the foundation commenced in 1756; the building was executed between June, 1757, and October, 1759; and the lantern lighted on the 16th of October of that year. This work, the greatest of its kind hitherto undertaken, remains to this day a stable monument of Smeaton's engineering skill.

‡ This castle stands in the middle of a village, to which it gives its name. In the vicinity are stone and marble quarries, clay works, and potteries. The castle was founded in the tenth century, and was long one of the strongest fortresses in the kingdom. Here King Edward the Martyr was murdered by his mother, Elfrida, about A.D. 960; and King John, during his disputes with the barons, kept his regalia here for safety. Here, also, in 1643, Lady Bankes defended the castle for six weeks against Charles I. It was dismantled by Fairfax in 1645.

Any hard substance, broken into small pieces, will serve for the solid part of concrete. That most used is gravel or ballast. This should not be sifted too fine, as the sand which is left will mix with the lime, and form a sort of mortar, and so assist to cement the stones together. If broken stones or masons' chips are used, it is well to mix some sharp sand with them. The general rule is, that no piece should exceed a hen's egg in size. In this country, the lime is generally ground, and used hot. It is mixed with the ballast by scattering it amongst the stones, and turning them over with a shovel, water being at the same time thrown upon the mass. It is then immediately filled into the trenches. This has sometimes been done by shooting it from stages erected for the purpose. This practice has, however, been much and justly censured by the greatest engineers; the proper method being to put the concrete down in layers of about one foot in thickness, to level each course, and ram it well down. In support of this plan we may quote the words of Mr. George Burnell, C.E. (on limes, concretes, and cements): "In almost every work upon the art of construction we meet with descriptions of modes of making concrete. It is, however, very discouraging to observe that, in spite of all that may be said, the majority of architects and engineers treat the matter with such utter indifference that the old imperfect systems are still retained, and the conduct of these works is left almost invariably to some rule-of-thumb workman, who only knows that he has been accustomed to make concrete in a certain manner, without knowing any one of the principles which regulate the action of the materials he works with. We thus find that the bulk of the concrete made in and near London, where the building art ought to be the most advanced, is made simply by turning over the ground stone-lime, a very moderately hydraulic one, by the way,* amongst the gravel. It is then put into barrows and shot down from a stage. Such a mode of proceeding is rapid and economical, but it is eminently unscientific, leading, doubtlessly, to the waste of material we so often witness; for the practice is to make the concrete about one-third thicker than would be at all necessary if the process of making it were more perfect. It cannot be too often repeated, that the first condition necessary to obtain a good concrete or *béton*, is that the lime should be brought to the state of a perfect hydrate,† before being mixed with the nuclei‡ which it is to surround. It should, therefore, be reduced to the state of a thick paste, and made into a mortar, before it is mingled with the gravel. Instead of being thrown down from a height, and left to arrange itself as it best may, it should be wheeled in on a level, and beaten with a rammer; for we find that when thrown thus from a height the materials separate, and the bottom parts of a thick bed of concrete are without the proper proportion of lime. The advantage of making the lime into mortar previously, is that it fills in a much more perfect manner the intervals of the gravel or stones, and, in fact, renders the concrete what it is meant to be, an imperfect species of rubble masonry."

Where the soil consists of running sand or soft clay, the area of the foundation must be enclosed by sheet piling. This consists of piles driven close to each other, so as to form a wall which encloses the soil, and prevents the softer portion from spreading out under the superincumbent weight of the building. Sometimes as much as possible of the soft matter is removed and replaced by *béton*, or concrete, the heads of the piles sawn off level, and a kind of wooden platform built on this support. In other cases piles may be driven in at certain distances apart over the entire area enclosed by the sheet piling, the spaces between these piles being filled in with stones or concrete, and a solid flooring constructed on this foundation.

It may be remarked that concrete is now used in making the walls of buildings as well as their foundations, the walls being raised about one or two feet at a time by throwing concrete into a frame-work or box formed of iron plates, which is raised from time to time as often as is necessary until the wall has been built up to the height required.

* *Hydraulic lime* is such as possesses the quality of setting or hardening under water.

† *Hydrates* are substances in which a definite quantity of water is chemically combined with a definite quantity of some other constituent.

‡ *Nuclei*, plural of *nucleus*, a substance, however small, which forms a centre around which other matters gather.

PROJECTION.—III.

PROJECTION OF PRISMS—SECTIONS.

A PRISM has already been defined to be a solid whose opposite ends are equal and similar plane figures, and whose sides uniting the ends are parallelograms. It will be clear, then, that the lessons previously given are but stepping-stones to the present, and we can therefore at once proceed to

PROJECTION OF PRISMS.

To Project a Square Prism.—Width of side ½ inch, length 1½ (or 1·5) inch. The prism is in this lesson placed so that its axis is vertical, and its long faces are at 45° to the vertical plane.

Draw the square, Fig. 21, which is the plan of the prism, its sides being at 45° to the intersecting line; perpendiculars drawn from the angles will give the edges of the elevation, which are to be terminated by an horizontal line at 1½ inch from the base.

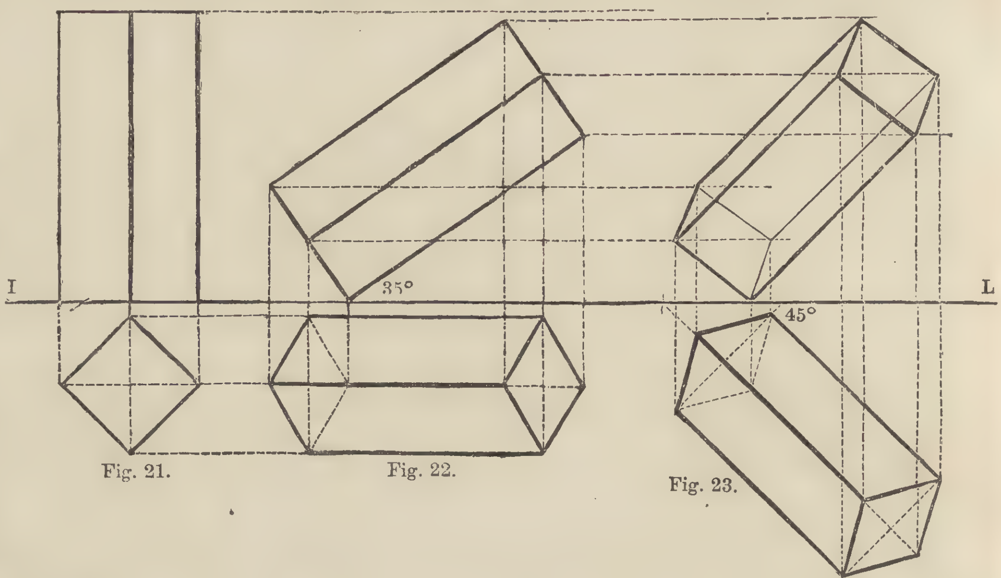


Fig. 21. Fig. 22. Fig. 23.

Fig. 22.—It is now required to draw the elevation and plan when the axis, although remaining parallel to the vertical, is at 35° to the horizontal plane.

Now it will be evident that as far as the elevation is concerned, it will merely be altered in *position*, not in *form*, which change is effected by allowing the object to rest on one angle of the base, and continuing the motion until one edge of the elevation (the edges being parallel to the axis) is at 35° to the horizontal plane. It will therefore only be necessary to copy the previous elevation, inclining it at the required angle. This motion, however, whilst causing so slight an alteration in the elevation, causes an entire change in the plan; for whilst in the first position the plans of the edges were mere *points* (see Fig. 1), which united form the base, the square of the top being immediately *over* this, as in a line placed vertically, the upper extremity is directly over the lower; but the moment the line is inclined, the plan, which was previously a point, becomes a line, the length of which increases as the object approaches the horizontal. (See Fig. 4.)

But although the position of the lines is altered, as far as their relation to the horizontal plane is concerned, they still remain *parallel* to the *vertical* plane; and if the eye were placed immediately over the object, the widths across from the front to the back would be seen to be the same throughout the motion. Therefore, from the angles of the plan of Fig. 21 draw horizontal lines, which will give the widths of the two upper sides; the two under them, being the same, will be hidden by them. The length of the diagonal of the top and bottom, which is at right angles to the vertical plane, thus remains unaltered, but the diagonal which is inclined will necessarily become shortened. This will be seen in continuing the projection of the plan. Draw perpendiculars from the two extremities of the line which is the edge elevation of the end, to cut the middle line of the three horizontals previously drawn in the lower plane. From the middle point of the edge elevation then draw a perpendicular which will cut the *two* outer horizontal lines, and thus four points will be obtained, and these united will give the *lozenge*, which is the plan of the *square* end when inclined. (Refer to Fig. 14.) The lower end of the prism will be obtained in a similar manner.

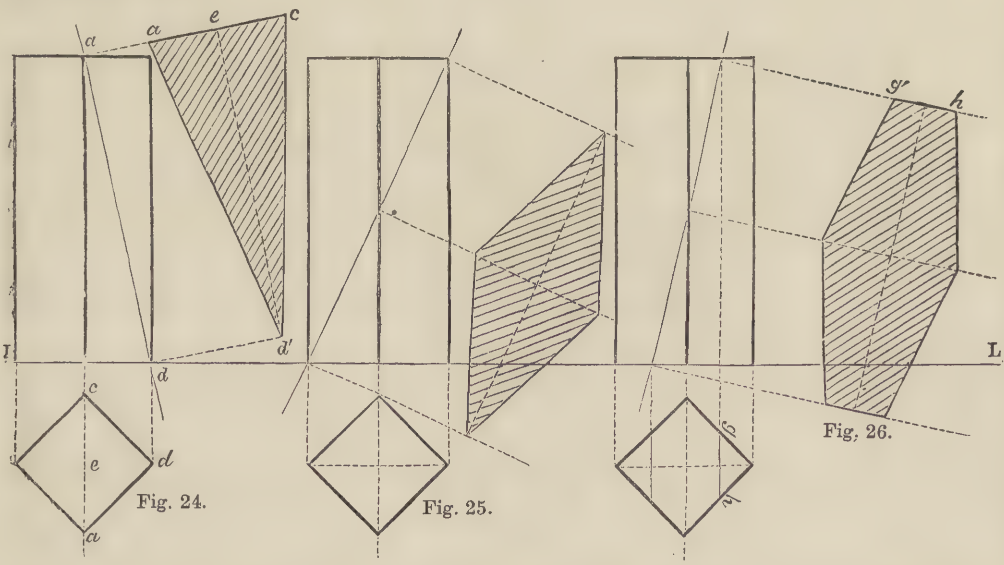


Fig. 24. Fig. 25. Fig. 26.

Fig. 23.—It is now required that the object shall be rotated on its solid angle, so that the axis shall be at a *compound* angle —that is, it shall not only be obliquely placed in relation to the horizontal, but to the vertical plane. This operation has been shown in Fig. 5, and it is therefore only necessary to remind the student that, so long as the inclination of a line in relation to the horizontal plane is not altered, no change but that of *position* will occur in the plan; for, however much the object may

be rotated *horizontally*, the length of the space it overhangs will not be extended, nor will the *heights* of any of the points be altered; and this knowledge is the key to the projection of Fig. 23.

Place the plan of Fig. 22 so that its axis and the edges parallel to it are at 45° to the intersecting line, then from each point in the plan raise perpendiculars, and intersect them by horizontals drawn from the corresponding angles in the elevation of Fig. 22. Join the points so obtained, and the result will be the form shown in the upper projection of Fig. 23.

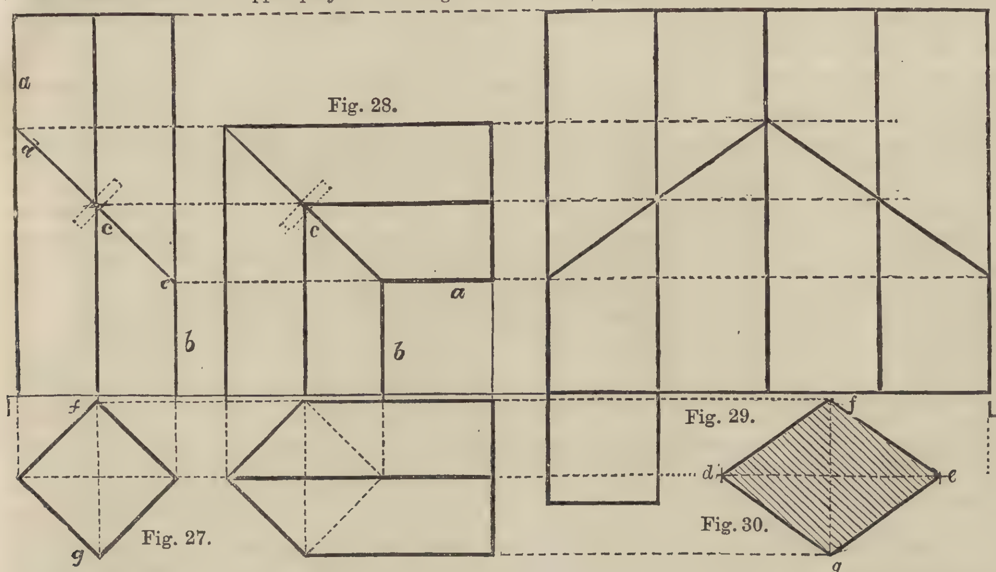


Fig. 27. Fig. 28. Fig. 29. Fig. 30.

SECTIONS.

Fig. 24 is the plan and elevation of the square prism forming the subject of the last exercise. It is required to find the true shape of a section or cutting, caused by a plane passing through the prism in the direction of the line $a\ d$. This plane of section would cut through the diagonal $a\ c$ of the top, and the angle d of the bottom. Draw the dotted lines $a\ c$ and $d\ d'$ at right angles to the line of section, and at any part draw $d'\ e$ parallel to $a\ d$. Now it will be evident that this will be the greatest length of the section, and that the *width* will be *somewhere* on each side of e; but where? How *wide* will the section be? These are questions which the student will do well to ask himself.

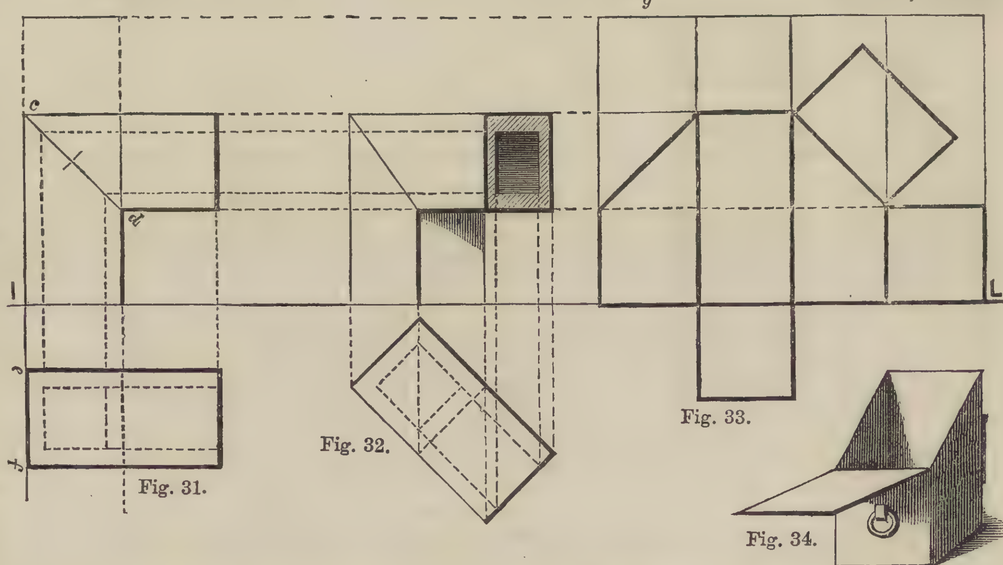


Fig. 31. Fig. 32. Fig. 33. Fig. 34.

Now it is clear that in passing through $a\ c$, the section-line cuts the object in the widest part; therefore, if the eye be carried down from a in the elevation to $a\ c$ in the plan, it will be seen that the real width on each side of the centre e is $e\ a$ and $e\ c$; therefore, if these lengths be set off on each side of e in the section-line, and the points joined to d', then $a\ c\ d'$ will be the true section.

In Fig. 25 the section-plane passes from one angle of the top to the opposite angle of the bottom, cutting through the middle of the two edges. The length will of course be equal to that of the section-line, and the width, $a\ c$, as in the last figure.

In Fig. 26 the section-plane passes from a line connecting the middle points of two adjacent edges of the top, to a similar line on the two opposite edges of the base. The width of the section at its middle will be equal to the diagonal $a\ c$, and at the top and bottom it will be equal to $g\ h$. It is usual to cover sections with lines at 45° to their central line.

Fig. 27 is the plan and elevation of a square prism, similar to that which formed the subject of the last exercise. Now if this be made of wood, and cut so that the section passes through the axis at 45°, and a pin, c, be fixed in the centre of the section, at right angles to its surface, the upper portion may be rotated on the pin, so that the short line (a) will move to b, and be at right angles to it, and the object will be represented by the elevation and plan in Fig. 28.

Fig. 29 is the development, which will show how a metal plate may be cut without waste, so as to make a square pipe to turn a corner, or form an elbow. The true section is shown in Fig. 30, its length being equal to $d\ e$, and its width to $f\ g$.

Fig. 31 shows the plan and elevation of a piece of a square wooden pipe, when the plane of the section, instead of passing from angle to angle, as in the last figure, passes from side to side, so that the section will be a rectangle, the length of which will be equal to $c\ d$, and the width to $e\ f$, instead of a lozenge form, as in the former case.

Here, too, the upper portion may be rotated on a centre, so as to join in a right angle.

Fig. 32 is a projection of the object when placed at an angle to the vertical plane.

Fig. 33 is the development, with the shape of the section attached. It will be seen that this form will give both parts of

the object, the only difference being that in the portion formed by the fine lines the joint or seam will be in one of the edges at the *back*, whilst in the other it will be in the *front*.

Fig. 34 shows how this form is applied in constructing a common sheet-iron coal-scuttle, the lid being the covering of the section.

TECHNICAL EDUCATION ON THE CONTINENT.—II.

BY ELLIS A. DAVIDSON.

TECHNICAL EDUCATION GENERALLY (*continued*).

In order, however, fully to appreciate the schools for the various classes of society existing on the Continent, we must carry our examination into our own deficiency still farther. Let us, therefore, take the case of a young gentleman who is to be an engineer, and who is placed for a few years in "the works." He has had the benefit of what is called a good education in a private school, or, perhaps, in one of our public seminaries. He has spent many hours on classics, has gone through the usual school course of mathematics; he has perhaps learnt chemistry and mechanics from books; his powers of drawing have been cultivated to the extent of manufacturing "Views on the Rhine," "Ruined Castles by moonlight" (the only true parts of which are the *ruin* and the *moonshine* of such a system), and a few shaded heads. These look well to take home, when mounted, etc., by the drawing-master. In a few instances he may have drawn a steam-engine from a copy, without knowing anything of its action.

Again, drawing being in many schools treated as an extra, taught on the half-holidays, the pupils attend instead of enjoying their freedom, and the lesson is merely thought of as another form of amusement. The studies of Practical Geometry, projection, Mechanical Drawing proper, and Perspective are ignored, whilst the teachers are mostly artists, incompetent to give the instruction a technical tendency.

Chemistry and Practical Mechanics are scarcely better taught, for it may safely be asserted that a proper laboratory and a collection of working models of machinery, or parts of them, form features in but few of our public or private schools; and it is scarcely necessary to point out that, unless the pupil receives his chemistry lessons in the laboratory, and is allowed to work out experiments there, the time spent in book-learning is almost wasted.

The instruction our lads receive in architectural drawing whilst at school is, as a rule, of a similarly unpractical character, the highest achievement being a measured drawing, copied from an elevation or plan, without the slightest knowledge of the scientific principles of building construction, or of the method by which the elevations or sections are projected from given data.

On entering the office of an architect or civil engineer, the youth has to attend to various office duties—to make tracings, etc., and to get a knowledge of his profession in the best way he can; for it must be remembered that in a place where all are engaged in their business, it is not any one's especial duty to teach him, though it must be said that the clerks and draughtsmen are always most willing to impart such instruction as they are able to give; but their competency, like their time, is limited, so that our embryo architect, like the young artisan whose progress has been sketched, grows up to repeat what has been done by others, not daring to invent, being by very virtue of his education (or rather the want of it) wholly deficient of the materials necessary for invention, and of the scientific principles which should guide him in designing.

Happily, these remarks do not apply to all our schools, but the few which form exceptions only serve by their very brilliancy to show the prevailing deficiency.

The evening classes for science which have been established under the auspices of the Department of Science and Art, are doing a great and useful work in offering to young men sound instruction by properly certificated teachers; but it is scarcely the purpose of such classes to teach the elementary portions of the various subjects. These should form a part of the work of primary schools for all classes of society, and the science schools should take up the studies at a higher stage, when the pupils, more advanced in years, and with intellect improved by previous training, feeling in their daily avocations the use of the elementary education they have received and the necessity for extended knowledge, enter into the lessons with earnestness and appreciation. Whereas, to adults totally uninitiated, the necessary ruggedness of the first few steps of the road to learning, however much the tact and power of a clever teacher may enable him to smoothen it, is still irksome in some cases, causing many to droop by the way and to discontinue their attendance.

On the Continent, under the heads of "Gewerbschulen," "Real Schulen," and "Écoles Polytechniques," institutions for practical studies have been in operation for many years past; and it is proposed in these papers to give a detailed account of the systems pursued, and the results attained in a number of these schools as obtained from the most authentic sources, in the hope that some hints may be taken from the information given, which may be applied in the promulgation and management of similar schools in this country.

The numerous sets of works executed in the various technical schools of France and Germany, which were shown in the Paris International Exhibition in 1867, prove the great value attached to scientific drawing; and it is intended in these papers to give a general account of these, reserving the practical working out of them for the lessons in "Technical Drawing."

In the schools referred to the studies are, as their names imply, of a *real* and practical character. Students learn not only how to make a drawing *of* a machine, but to make the working drawings from which a machine may be constructed, and in many cases to make the objects from the drawings.

This must tend to show the pupils the importance of accurate measurement and correct delineation. They learn not only that the drawings must be exact, or they could not be worked from; but in turning or putting together the various parts, they do so with more readiness from having studied the construction on paper.

The various models, etc., used in the Continental schools will be referred to as these papers proceed. The leading sets of studies show an excellent mode of combining several elementary manual processes with scientific instruction, and so avoiding a difficulty often experienced in instructing persons whose minds are in advance of their hands, who can "think out" a subject, but who cannot execute it. Many practical teachers will have observed the diffidence with which a student, who has been allowed to continue his geometrical drawing in pencil for a long period, commences to work in ink, and the tendency to spoil a drawing scientifically correct by the tinting, either with the draw-pen or with the brush.

The system pursued in the Austrian schools seems calculated to overcome the manual difficulties contemporaneously with the elementary scientific instruction. When the geometrical figures have been correctly executed with the pencil, they are from the first lessons inked, great neatness of line and accuracy of intersection being insisted upon; they are then coloured with flat-washes, or sectioned over variously with the pen, the inscribed and containing figures being tinted with complementary colours. Where parts of circles cover each other, each circle is coloured with a primary, so that the part overlapped becomes a secondary colour, etc. This system is thoroughly carried out, and thus at the same period the student is learning practical geometry, shading with the pen, the use of the brush and elementary colouring; and thus, by the time he reaches the studies of mechanical or architectural construction, he is able to draw and colour with tolerable correctness.

In these studies, too, all the shading is scientifically worked out, all the shadows of or on the sphere are projected in circles, each circle separately according to position, and so accurately that at but a short distance the separate circles are not observable, but a beautiful roundness of form is the result.

Amongst the excellent collection of scientific drawings exhibited in Paris in 1867, was a set shown by the Industrial Union of the Grand Duchy of Hesse, which will be again referred to, being the works of pupils in schools for workmen of the duchy. These works were the more valuable, as it was evident that they had not been specially executed for exhibition, but had been taken from the daily studies of the pupils. They indicate, as indeed do all the works of the Continental schools, an absolute connection between the scientific and artistic

studies, since all the science students seem to learn free-hand and ornamental drawing, shading, etc., as well as mechanical drawing.

The whole subject of technical drawing, whilst it has been much neglected in this country, has been thoroughly systematised on the Continent, and the foreign schools possess completely organised sets of examples, combining the study of drawing with that of construction adapted to the various branches, in which we have hitherto been very deficient. It is hoped, however, that this want is now being gradually diminished. The Technical Manuals, published by the proprietors of THE POPULAR EDUCATOR, and the Technical Lessons given in these pages, are designed specially to remedy the evil so long and so deeply felt; and it is encouraging to our English artisans to know that in the compilation of these the author has received and is daily receiving assistance and the warmest co-operation from the heads of the Continental schools, and from the Royal Board of Workmen's Schools of Wurtemberg, etc. etc.

Amongst the most important features in the systems of teaching in the Continental schools are the excellent collections of models for teaching science. The experience of all practical teachers tends to show that however good printed diagrams may be, no real conception of forms can be obtained without the aid of solid models, for even though the pupils thoroughly understand the *diagram*, the form there given is only such as would be correct in *one position*, and it is sometimes impossible from that one view to form an accurate idea of what shape may be presented by the smallest rotation, depression, or elevation of the object. In this "Projection" differs from "Perspective," the first rendering the object as it is, the other as it appears; and in this the knowledge of the form and the imagination generally offer some assistance; but in Projection it is not so, point by point has to be obtained, which, when united by lines, develop forms which to the student are often surprising. Even if the subject has been worked out on the black board, and followed line by line by the students, they get the diagram copied, but they do not receive a lesson such as might have been given by the aid of a block or two of wood or a sheet of cardboard or tin.

The sets of models used on the Continent for illustrating lectures on projection, mechanism, building construction, etc., are of infinite use to the teacher. Some of them have already been reproduced in this country, and it is intended to arrange for the production of sets of models adapted to each branch of industry, and at a price which shall bring them within the means of working men's classes and schools.

In the whole group of studies adapted for boiler-makers, tin-plate workers, etc. etc., the study of "development" is of the utmost importance—how the shape the metal is to be cut when flat, so that when rolled, folded, or bent, it may assume the required form, *may* be worked out on the black board; but how much is the value of the lesson increased if a model, made of cardboard or some other material, be used, so that it may be first exhibited in its complete form, then flattened out, and the students shown how the result is obtained. They then work with confidence, for they know what they are working for, whilst if they only copy the lines as worked by the teacher they are in a degree in the dark until the whole is completed, and even then the black board cannot be bent or folded, so that after all they *believe because they are told* that the form is correct.

Again, let it be required to teach a class of artisans to shape metal so as to form a pipe with two elbow-joints. These students will most likely have been accustomed to cut, file, and alter separate pieces of *piping* so as to get the joints at the angles, and it would be difficult to convince them that the *flat metal* may at once be cut in properly constructed curves, so that the parts on being rolled into a cylindrical form will fit each other at the required angles without any waste of metal or time; but if a cardboard model has been obtained and exhibited in the course of the lesson, first complete, then the two ends rotated until at the required angle, and finally the three parts opened out to show the development of the surfaces and sections, the students will understand what they are about, will work with infinite pleasure, and will be encouraged to think out similar developments adapted to their own trades. This and numerous subjects are fully worked out in our lessons on "Projection."

SEATS OF INDUSTRY.—I.

BIRMINGHAM.

BY H. R. FOX BOURNE.

AMONG the seats of modern industry, English and foreign, which in this series of papers will be briefly described, Birmingham is fairly entitled to the first place. "I sell here," Matthew Boulton, Watt's partner in the manufacture of steam-engines, said to Boswell in 1776—"I sell here, sir, what all the world desires to have, *power*." And long before the steam-engine was invented, Birmingham took the lead in the production of the various tools by which other towns have been able to grow as homes of special industries.

Now the busiest hardware town in England, it is also, perhaps, the oldest. Tradition and local antiquities support the belief that it was a place of note—"very eminent for most commodities made of iron," according to the historian Dugdale—even before Britain was a Roman province. Its primitive inhabitants may have made Boadicea's war-chariots, and spears for her warriors; at any rate, they set the fashion of metal-working, which has thriven among their successors ever since. "I came through a pretty street as ever I entered," says Leland, the quaint traveller of Henry VIII.'s reign, "into Birmingham town. There be many smiths in the town, that use to make knives and all manner of cutting tools, and many lorimers that make bits, and a great many nailers, so that a great part of the town is maintained by smiths, who have iron and coal out of Staffordshire." Iron and coal out of Staffordshire have continued to feed the staple trades of Birmingham, and by those trades it has been made more than a hundred times as great as it was in Leland's day. Its growth, however, has been rapid only in recent times. Two centuries ago it had about 5,000 inhabitants, and ninety years ago some 50,000. At the time of the census taken in 1861, the population numbered nearly 300,000, and there cannot now be fewer than 350,000 persons crowded into an area little more than two miles long and nearly as broad, and most of them directly connected with the great hardware industries which, having their centres in Birmingham itself, spread over all the adjoining districts and help to supply all the world with steam-engines and pins, pens, guns, and a thousand and one other articles of various sort and use.

Steam-engines rank first. Boulton said truly that in selling them he sold power; and the new power, that has effected a revolution in all manufacturing enterprise, has wrought a wonderful change in the industries of Birmingham. A hundred years ago, when Boulton was a young man, the town was fairly described by Burke as "the toy-shop of Europe." In it swords, nails, and sober implements of many kinds were made and sold; but it was especially famous for its production of trinkets and nicknacks. John Taylor, then its richest and most influential manufacturer, made his fortune out of buttons, buckles, snuff-boxes, ornamental clocks, and other fancy articles. During some years, £800 worth of buttons were turned out of his workshop every week, and one of his workmen earned twelve shillings a day by painting snuff-boxes for a farthing a-piece; while his shop-sweepings, containing quicksilver and scraps of gold, silver, and brass, were sold for £1,000 a year. Boulton carried on the same sort of trade at Snow Hill, then the centre of manufacturing energy in the town, during some years previous to 1762, when he transferred his business to Soho, a miserable village two miles out of the town, where a water-mill had been set up, and he saw an opportunity of carrying on his old trade of toy-making with greater advantage. That he did, and Soho became famous for its manufacture of buckles, buttons, and watch-chains, candlesticks, urns, ormolu wares, and the like. He made in it every variety of "Brummagem goods," trying always to redeem the town from the ill repute which then, even more than now, it had by reason of the trumpery articles which inferior and dishonest manufacturers produced. "The prejudice that Birmingham hath so justly established against itself," he said, "makes every fault conspicuous in all articles that have the least pretensions to taste. How can I expect the public to countenance rubbish from Soho while they can procure sound and perfect work from any other quarter?" Boulton's work was sound and perfect, and he made great profit out of it before it was applied in a new and very notable way in 1774. In that year he entered into part-

nership with James Watt, whose invention of the steam-engine had been lying idle during nine years for want of a shrewd man of business to work out the ideas of the brilliant man of genius. This is not the place for rehearsal of the memorable exploits of Boulton and Watt in manufacturing steam-engines and convincing the world of their value. But the partnership and its results must be noted as forming the chief episode in the industrial history of Birmingham. The first steam-engine was made at Soho in 1775. The Soho Foundry now covers an area of ten acres, and in it, prior to 1866, there had been manufactured 1,878 steam-engines, with a nominal horse-power of 70,958, but able to do more actual work than could be performed by 250,000 horses. Bearing the illustrious title of Boulton and Watt until 1848, the firm conducting this foundry is now known as James Watt and Co. In Soho and its neighbourhood other great establishments for the construction of steam-engines have grown out of the good example of Matthew Boulton, "the father of Birmingham," who may also be claimed as a foster-parent by every one of the hundred towns, in and out of England, which find their profit in engine-making.

The staple industries of Birmingham, however, are concerned rather with the construction of metal and other goods by help of steam-engines than with the manufacture of steam-engines themselves. Among these brass manufactures are the most important. About 90,000 tons of copper are consumed each year in all parts of the world. Of that quantity some 60,000 tons are procured in England, or brought into it, and nearly 20,000 tons go to Birmingham, to be converted into brass by the addition of 11,000 or more tons of zinc. The entire supply of copper and zinc worked up in Birmingham, including old brass re-wrought, in 1865, was nearly 40,000 tons, and its value as raw material about £2,400,000. There were 50 manufacturers of brass and brass goods in the town in 1800. In 1835 the number had risen to 160, and in 1865 to 216. In the latter year about 7,000 men and over 2,000 women were directly engaged in these trades. As they require delicate manipulation, and furnish good wages to all who work at them, their importance to the town is very great.

Another highly-paid calling, closely connected with brass-work, for which Birmingham is famous, is the gun-trade. The story goes that William III., soon after his accession, was complaining that England made no guns, and that he had to send all the way to Holland for them, when Sir Richard Newdigate reminded him that "the men of Birmingham were masters of all that skill and metal could do," and showed him that their guns were at any rate as good as any to be procured abroad. Thereupon the local manufacturers were ordered to make weapons for the English soldiers, and the business has been mainly carried on by their successors ever since. Besides the great Government factories, more than 600 employers are concerned in gun-making and kindred trades. Nearly 4,000 men and boys are engaged in producing the materials, and rather more in setting up and finishing them. Besides the weapons supplied for the English troops, others—good, bad, and indifferent—are made in great numbers for private customers at home and foreigners of every nation.

A more harmless trade connected with brass manufacture, in which Birmingham excels, is pin-making. Pins used to be made much of, as illustrating the value of division of labour, the services of fourteen persons being required for the perfecting of a single pin. Now, however, the whole work is done almost instantaneously by help of an ingenious machine invented in 1824 by an American named Wright. During a single revolution of a wheel the requisite length of brass wire is cut off, pointed at one end, and provided with a head at the other, leaving nothing to be done but the whitening, which is effected by boiling in a copper vessel with tin and bitartrate of potash. One Birmingham house, that of Edelsten and Williams, turns three tons of brass wire into pins each week; and there are twenty other houses devoted to the same trade.

There are also twenty steel-pen manufactories, and most of them much larger than the pin-shops, in Birmingham. The growth of this trade is remarkable. Sixty years ago a steel pen was a curiosity, and, clumsily shaped as it was, could hardly be bought for five shillings. Ten years later the price was about a shilling; but before then Joseph Gillott had embarked in the business, and to him and to Josiah Mason are mainly due the improvements in the manufacture. Steel pens soon came into favour, and their increased use quickly reduced the price. In 1865 the Birmingham makers produced about 100,000 gross every week, and gave employment to nearly 400 men and boys and more than 2,000 women and girls. Unlike pins, pens are still produced by minute division of labour. They pass through at least twelve processes, yet the wholesale value of the commoner sorts is often as low as three-halfpence a gross.

Pins and pens will serve to show how, in Birmingham, the heaping of small things goes to make a great trade. The names of the trades, still justifying Burke's epithet, "the toy-shop of Europe," are legion. Of button-making alone there are still two or three dozen varieties, altogether giving work to about 180 employers and more than 6,000 labourers. The old gold and silver buttons that suited the foppery of last century have gone out of fashion, but their places have been taken by cheaper and more convenient articles. Linen, silk, and velvet buttons, steel, brass, bone, glass, pearl, and wood, are turned out by the million every week. Then there is a large trade in gilt watch-keys and cheap jewellery of every sort, a larger trade in screws and nails, chisels and other tools, and one larger still in fenders and stoves, bedsteads and other ironmongery.

One of the most interesting developments of the old "toy" trades of Birmingham is the manufacture of electro-plated goods. Silver-plating was introduced at Soho by Matthew Boulton more than a hundred years ago, and the rude chemistry of his day made it necessary for the silver coating upon copper to be very solid unless the article produced was in the course of a few weeks to become good for nothing. The modern process of electro-plating was only adopted about forty years ago. In 1838 Messrs. Elkington were employed in coating military and other metal ornaments with gold and silver in the old way, when they, or some chemists in their employ, conceived the plan of depositing costly metals on cheap ones by utilising the decomposing powers of an electric current. Out of their experiments resulted the finished process for which their house is still famous. They have now more than fifty rivals in Birmingham, and the trade, also carried on extensively in Sheffield and elsewhere, has become an important branch of British industry. There is electro-plating in gold as well as in silver, and by it Birmingham is able to give cheap gratification to the vanity of young men and maidens too poor to buy good trinkets. An instance of electro-plating at its cheapest and flimsiest appears in those miniature gilt lockets, supplied with tolerable likenesses of the Prince and Princess of Wales, which a few years ago were sold wholesale for a halfpenny a-piece.

Birmingham has some trades, also, which are not concerned in metal-working. In papier-mâché manufacture, started by Henry Clay, a native of the town, in 1772, it has had almost a monopoly ever since; and it is famous for its dressing-cases and other products of leather-working, its tortoiseshell goods, and the like. Nearly every month, it has been truly said, produces in Birmingham some new invention or some new trade.

The old and the new industries combine to make the town wonderfully prosperous. "The history of every trade and every manufactory," says Mr. Timmins, a competent local authority, "is one of rapid growth. Beginning as a small master, often working in his own house, with his wife and children to help him, the Birmingham workman has become a master, his trade has extended, his buildings have increased. He has used his house as a workshop, has annexed another, has built upon the garden or the yard, and consequently a large number of the manufactories are most irregular in style. Whenever the business has overgrown its early home, and it is necessary to remove or to rebuild, a better class of building is invariably adopted. The warehouses, the workshops, and the offices erected during the last few years, all show not only great attention to physical wants and sanitary laws, but generally some appreciation of ornament and some love of art. Birmingham is, in fact—Sheffield, perhaps, only excepted—the town of all others where social and personal freedom is extreme. The large number of small manufacturers are practically independent of the numerous factors and merchants they supply. The workmen, mostly untrammelled by trades' unions, are paid according to their merits, and skilled labour of all sorts is nearly always in demand. The enormous variety of the trades renders general bad trade almost impossible; for if one branch is slack, another is usually working full or even over time. In no town in England

is comfort more common, or wealth more equally diffused. If millionaires are few, absolute poverty and wretchedness are also rare. Dwellings, however humble, are not overcrowded, as in many large towns, and very rarely is more than one family found in one house." Birmingham is thus, on social grounds as well as on commercial, one of the most interesting of the great seats of English industry.

CHEMISTRY APPLIED TO THE ARTS.—I.

BY GEORGE GLADSTONE, F.C.S.

BLEACHING.

All the fabrics used for clothing and other purposes, which are made of cotton, flax, wool, jute, silk, and such like articles, are more or less coloured when they are first produced. Raw cotton is naturally almost white; but it is liable to be mixed with minute fragments of the husk, and other extraneous substances, besides grease and dirt, which destroy the purity of its character, and render it quite grey by the time it has passed through the spinning-mill and loom. Flax and jute are by nature rather dark-coloured; silk is always yellow; and wool is anything but white when in the fleece. None, therefore, of the goods made from these articles present a clean and inviting aspect when they leave the hands or machine of the weaver.

In order to render them fit for the market, they must not merely be washed, which would only remove the dirt, but they must generally be bleached, or, in other words, made white. Grey calicoes are not bleached, but the tint they possess prevents their being used for a great variety of purposes. If they have to be dyed or printed with patterns, it is still more important that the fabric should be bleached, because otherwise the colours or patterns would appear indistinct and dirty.

The bleaching process is therefore a very important one. It is one, however, that is continually going on without man's interference, of which most housewives find too many instances. We are all familiar with the power of the sunlight in fading carpets, curtains, etc., which are much exposed to its influence. Almost every article that can be named is subject to the same, timber and even stone losing much of their colour by exposure. The effect is increased by occasional showers of rain.

In the early ages man copied the process of Nature, and exposed his manufactures to these influences for the purpose of rendering them white. Water is generally so cheap, and sunlight costs nothing at all, that modern science has not altogether supplanted this plan; but in these days, dispatch is a matter of so much importance that we cannot wait while Dame Nature does her work, and we must therefore either hurry her on, or find some more expeditious method.

About 100 years ago, the attention of chemists was drawn to a substance which is now known to be one of the most common, and at the same time important, chemical elements—chlorine. In combination with sodium, it forms the well-known table-salt (chloride of sodium), and is therefore one of the most widespread substances in Nature. It was not long before its bleaching qualities were discovered, and then commenced a new era in the art of which we are now writing. The best manner of using the chlorine was the subject of many experiments, and improvements have from time to time been suggested; but still chlorine, in one form or another, is the article upon which the bleacher of cotton relies. A great economy, both of time and labour, is the result; the effect which could formerly have been gained only by a vast amount of labour, and an exposure of months to the atmospheric influences, being now attained within an equal number of days.

What is the principle upon which chlorine acts in the bleaching of goods made of vegetable fibres? Let us get at the philosophy of the matter first, and then proceed to the working of it out in actual practice. The chemical process amounts simply to this—to give the chlorine employed the opportunity of entering into combination with the colouring matter in the fabric to be bleached, the result of which is the formation of a white compound which can be readily separated from the manufactured article.

There are, however, many niceties in the operation which need to be borne in mind, in order to produce a satisfactory result. Raw cotton imbibes a certain amount of dirt and grease in the processes of picking, ginning, and sending from the place of growth to the manufacturing district; and in the subsequent processes of spinning into yarn, and of weaving into calico or other fabrics, a good deal more of both these impurities is acquired. It is important to get rid of these, and more particularly the grease, before the goods are subjected to the actual operation of bleaching. The mere dirt is easily removed by the ordinary process of washing, which is therefore one of the first things to be done. Grease or oil is not, however, to be got rid of by this means, and the quantity of these troublesome ingredients when the goods come out of the loom is by no means inconsiderable. The simplest and cheapest way of purifying the fabric from these is to convert them into a soap, by boiling the goods in a solution of lime-water or any alkali. The soap thus formed is easily separated, and the material is then ready to be subjected to the bleaching process. During these preparatory operations, which consist of alternate washings in lime-water, acids, and caustic alkalis, between each of which the fabric is thoroughly rinsed in pure water, the article operated upon loses a good deal of its colour, though the most important have yet to follow.

There are two ways of conducting the succeeding process: the one is by bringing the goods under the influence of chlorine in its free state (either as a gas or dissolved in water), and the other by using the chlorine in combination with a base, such as calcium, of which lime is the oxide. The former is adopted more generally on the Continent, the latter in England. The former is very effective and rapid in its operation, but it involves a certain amount of risk, because the chlorine in that case is liable to do too much, and destroy or burn the fibre itself; the latter is more easily regulated, so that there is less risk of injuring the strength of the calico. Even in this case, it is necessary to adjust with care the strength of the solution of chloride of lime, its temperature, and the time employed; because an increase of temperature, or a prolongation of the time, will operate as prejudicially as an excessive quantity of the bleaching powder. The colouring matter is the first attacked, and as soon as that has been sufficiently acted upon, the fabric should be withdrawn from any further influence.

The chloride of lime is dissolved in a large quantity of water, to make a bath into which the goods are to be placed after it is reduced to such strength as is desired, a point which varies considerably according to the quality and character of the goods to be bleached. Into this solution the cloth is put, and remains there generally for about six hours, by which time the chloride of lime has been taken up. It then passes into a weak bath of sulphuric acid, when the acid attacks the calcium, forming sulphate of calcium, and leaving the chlorine free to act upon the colouring matter. The sulphate is easily removed by steeping in water for eight or ten hours; and the colouring matter, having been already decomposed by the chlorine, is got rid of by boiling for about eight hours in a solution of caustic or carbonate of soda. The goods are finally passed through a bath of weak acid, to prevent the chance of their subsequently turning colour in consequence of any resinous matter remaining behind, and are then dressed and prepared for market.

The time occupied in bleaching cotton goods by the agency of chlorine need not occupy more than two days. It is, however, better to take rather more time, as the most expeditious mode involves the use of rather stronger solutions than are desirable; and a very thorough washing between the various steps of the process is of importance, because otherwise the fabric is liable, in course of time, to turn yellowish and spotty in some places. Care in this respect is all the more important if the goods are intended to be dyed or printed, because the colours are certain to be more or less affected if any of the ingredients used should remain behind, or have entered into combination with the fibre itself. The minute details vary considerably in different establishments, as well as according to the class of goods in hand. The solutions of the alkalis are generally prepared by dissolving a certain weight of the substance in a given quantity of water; but as chloride of lime is very apt to lose its strength by keeping, it is usually tested, by observing in a graduated tube how much is required to neutralise a standard solution of indigo, a test which is found in practice to be sufficiently exact.

The process of bleaching linen is somewhat different from the foregoing, though the same in principle. While cotton goods lose at the outside 10 per cent. of their weight, linens lose at

least 30 per cent. by being bleached. This arises from the large amount of colouring matter in the flax, some of which is even imbibed during the process of retting to which the flax plant is subjected in order to separate the fibre from the husk. The great quantity of colouring and resinous matters which have to be got rid of, render the bleaching of flax a much more tedious process than that of cotton, because they prevent the chloride of lime from penetrating the fibre completely during the short time that it is exposed to the influence of this agent; and many bleachers combine the modern chemical process with the old system of exposure to the elements, which, though longer, saves the repetition of some of the mechanical operations. Upon this plan the process generally occupies from six weeks to two months, though by adopting the artificial expedients it need not occupy more than about one-third of this time.

The animal substances used in the manufacture of clothing cannot be treated in the same way, for were they subjected to the operation adopted in the bleaching of vegetable fibres, the material itself would be so far destroyed as to render the goods comparatively valueless. The most important of these substances are wool and silk. They must be described separately.

Wool, it is well known, contains a very large amount of grease, and this is only very imperfectly removed by the process of scouring to which it is subjected before the wool is made into yarn. As in the case of cotton goods, the first thing to be done is to get rid of the greasy substances, but the alkaline leys used by the bleachers of calico to saponify the fatty matters would destroy the wool itself, so that another means of achieving this end has to be resorted to. The best article for the purpose, and which is therefore commonly used, is a mixture of water and stale urine, into a cold bath of which the wool is placed for about twenty minutes. During this time the carbonate of ammonia, evolved in the decomposition of the urea, combines with the grease, forming a substance which is readily removed by washing. If woollen goods are subjected to this treatment there is some difficulty, however, in getting rid of the disagreeable smell which clings to them, in consequence of which carbonate of soda and soap are generally substituted, though they are not so satisfactory in their action.

Though heat facilitates all the operations of the bleacher, it is necessary to avoid it when dealing with wool, because it would not only injure the fibre, but also make it shrink too much. Even in using cold water, the latter result has to be guarded against by keeping the goods stretched on a frame while passing through the various baths. To effect this with the greatest possible economy of liquid, the baths are fitted with two series of rollers, one near the bottom and the other near the top, and the fabric is drawn tightly over and under the rollers alternately.

Having thus prepared the article for the actual bleaching operation, it is now subjected to the action of sulphur, and not chlorine as in the case of cotton. The object of this treatment is not to remove the colouring matter from the wool, but merely to deprive the substance of its colour. It is applied in the form of sulphurous acid, which is a gas readily soluble in water, and may be used in either of these conditions according to the preference of the operator. Those who employ it in the gaseous state have large chambers provided in which the goods are hung up on wooden rails; the door is then hermetically shut, and the burning sulphur is introduced through an aperture in the floor, which is at once closed. In this way the air that is in the chamber becomes thoroughly impregnated with the gas, and the cloth, after an exposure of about twenty-four hours, is completely bleached. An immersion of four hours in water saturated with the gas is sufficient to produce the same result. The aqueous solution may easily be prepared by heating a mixture of sulphate of iron and sulphur in a retort connected by a pipe with the bath, so that the gas evolved should pass into the water, and be absorbed by it until thoroughly saturated, or until a sufficient strength be attained.

The process of bleaching silk is much simpler. In fact, except for special purposes, it can hardly be said to be actually bleached. The very pale tint to which it is usually reduced is attained by repeated boilings in water with soap, then immersion in a bath in which a little carbonate of soda is dissolved, and finally a short exposure to the action of a weak acid, the silk being well rinsed between each operation. A further decolorisation is, however, necessary, if the silk is subsequently to be dyed of a very delicate colour, in which case a weak solution of sulphurous acid is used. Much care has to be exercised throughout, lest the fibre should be affected, which would not only destroy its strength, but also deprive it of the brilliance which adds so much to its value.

The manufacture of the chloride of lime which is now the great agent in the bleaching of goods made of vegetable fibres, is a separate trade, and is principally carried on at the large chemical works in the neighbourhood of Glasgow, Newcastle, and Liverpool.

Machinery is used wherever practicable, in order to economise the cost of labour, and also time. The dash wheel, as it is called, is a most useful and simple contrivance, and one in almost constant requisition, being used in the frequent washings above described. It consists of a large cylinder or drum, divided lengthwise into four compartments, with a large aperture in the end of each, through which two or more pieces of cloth are inserted; water is then added, and connection being made with the steam-engine, the cylinder revolves rapidly, and the motion thus given to the pieces of cloth inside washes them thoroughly in less than ten minutes.

TECHNICAL DRAWING—III.

LINEAR DRAWING IN PARALLEL LINES—FREE-HAND DRAWING.

WE now proceed to give another example for practice in drawing parallel lines.

Fig. 6 is the plan and Fig. 7 is the sectional elevation of a platform in which the longitudinal sleepers, *b b b*, rest directly on the ground, and are kept in their places by the cross-sleepers, *a a a a a a*, which rest upon them. These are notched down, so that only half their thickness stands above the longitudinal sleepers. The spaces between these having been duly flushed up as in the previous example, the planking, *c c c c*, is placed *between* the cross-sleepers, of a thickness equal to the portion of their thickness which stands above the longitudinal timbers, the upper faces of the cross-sleepers themselves thus covering a portion of the surface of the platform.

To draw these figures, draw a line at A B, for the ends of the longitudinal sleepers; mark off the widths of these and of the spaces between them.

Now, knowing that the elevation is to be projected from the plan, you may as well carry on the process at the same time that you are drawing the first figure; therefore, at the proper distance, draw the ground-line of the elevation, C D (Fig. 7), and as you draw the longitudinal sleepers, carry down the lines which will give you the ends or sections of the timbers lettered *b b* in the elevation.

Returning to the plan, draw the cross-sleepers, *a a a a a a*, and the lines parallel to the longitudinal sleepers (not shown in the example) which bound the ends of the cross-sleepers, carried up, will give also the ends of the same timbers, and of the planking, in both plan and elevation. It will be seen that the portion of the cross-sleeper which is notched down on to the longitudinal timbers is represented by the width at *a* in the sectional elevation.

The section of the wall may, of course, now be drawn either to pattern, or may be worked to represent brickwork from either of the footings of walls which will be given in the lessons on Building Construction.

These drawings may now be coloured to represent fir, the colour usually employed for this purpose being raw sienna. This should be washed thinly over *all* the wood-work, and when dry the lower sleepers should be covered with sepia, the shadows cast by the upper on the lower timbers to be subsequently added with colour rather darker. When all the colouring is dry, the lines representing the graining are to be freely, but not too heavily, executed with this last darker shade of sepia; and it must be borne in mind that the graining is but secondary, and must not be over-done, and that in the example the lines are engraved closely in order to darken the lower timbers, so that the cross-sleepers may be more plainly visible; but in your drawing you attain this end by the wash of sepia, and therefore you are not required to shade your work in lines. In the ends of the sleepers shown in Fig. 7 it is, however, necessary to draw lines at 45°, in order to show that they are meant to represent sections.

Fig. 8 is the plan and Fig. 9 is the sectional elevation of the planking for the foundations of walls meeting at right angles. This plan, taken from an excellent German example, is such as might be applied in a case where it might not be necessary that the whole of the area should be planked.

To draw this example, draw the line A B (Fig. 8), and B C at right angles to it.

On B C mark off the widths of the lower sleepers and the spaces between them, and from these points draw the lines required for the timbers.

On A B mark off the widths of the upper sleepers and the spaces between them.

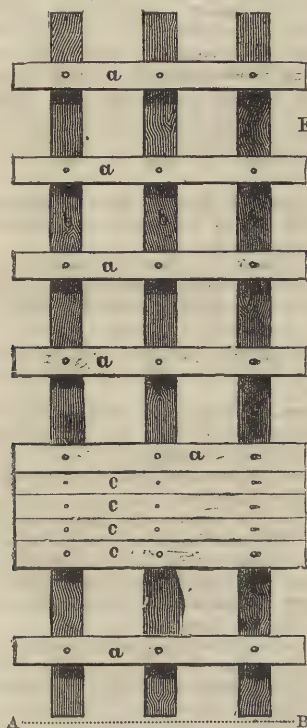


Fig. 6.

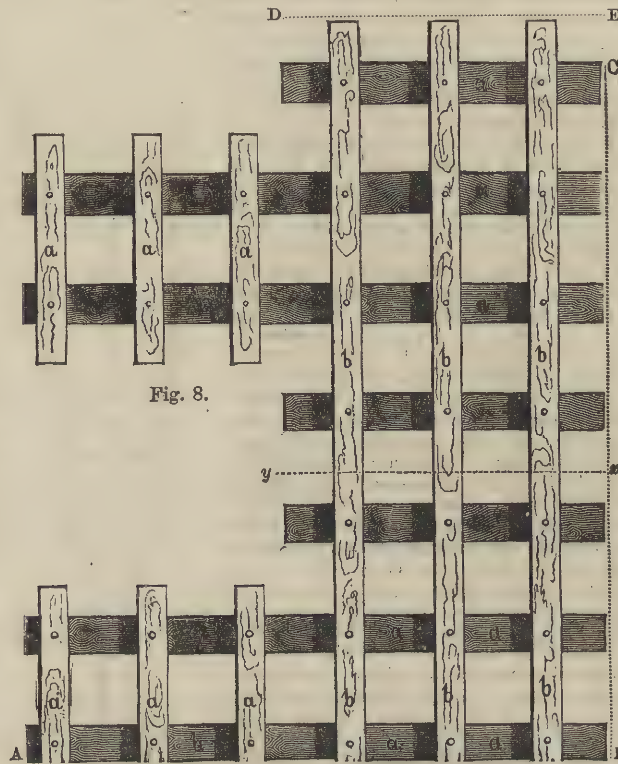


Fig. 8.

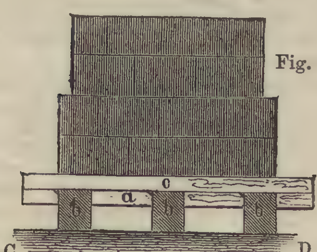


Fig. 7.

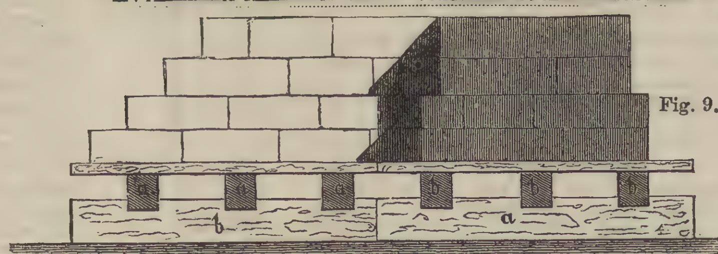


Fig. 9.

Although only three of these are continuous, it is advisable to draw all in pencil as if they were so, which ensures the distant set being immediately opposite to those in the front; and this mode of working is decidedly the more rapid.

It has been mentioned that it is desirable to draw all pencil lines longer than they will be required. We will now inquire why it is so.

Let us suppose the whole plan finished, as far as the pencilling is concerned, and that the next process is that of inking.

Now, of course, you know that the bevelled edge of your rule must be turned *downward*, in order to raise the edge so that the ink from the ruling-pen may not drag against it. This edge, however, obstructs, in a degree, your view of the lines you are to ink, and you either draw your pen past the angles of them or do not rule quite up to them. In either case the result is disagreeable, for you have either to scratch out the superfluous ends or to patch the line, which is exceedingly difficult to do neatly. But if you have drawn out the pencil-lines forming the edges of the sleepers, you at once see the exact length you are to ink; and this same result in inking the long lines will be attained by the pencil-line previously drawn at D E.

You are further advised never to scratch out any extraneous line until *after* you have coloured, and the drawing has thoroughly dried, as otherwise the colour will run into the roughened paper and cause a blotched appearance.

The sectional elevation (Fig. 9) can now be projected from the plan in the manner already explained. The shadow cast by the wall (which is a section on the line $y\,x$) is to be washed in with sepia. Be careful not to mix your colour too thick. Rather repeat the wash in order to darken it.

The lines for the courses of stones should be drawn after the colouring and shadowing, so that they may not be washed away.

OF FREEHAND DRAWING.

At this stage it is advisable that the student should be informed that *all* the drawing which is necessary for the artisan cannot be done with *rules and compasses*, but that some portion of the work must be drawn by "freehand."

It is important that a workman should be able, with his piece of chalk or pencil, to sketch roughly, by hand, the form of any object he is required to make, or that, visiting any exhibition or foreign country, he should be able to bring away with him drawings, however roughly done, of any tool, appliance, useful or ornamental article which may have attracted his attention.

Again, as the examples contained in this or any other work of a similar character advance, it will be seen that curved lines are of constant occurrence; and although some of them, which may be composed of arcs of circles, may be done with compasses, and others may be inked by means of the French curve, there are many which cannot be executed by any other means than by freehand, and there will occur little pieces of curved lines continuous with straight ones, which can always be more neatly joined by hand than by instruments, or which a certain amount of practice will enable the draughtsman to execute with his pen or pencil in less time than it would take him to find the centres. But this is not all. The study and practice of freehand drawing gives accuracy to the eye and refines the perceptive faculties; it enables a man to raise his ideas beyond mere straight lines, to cultivate his taste, and in many ways to add beauty to utility.

To the joiner these remarks apply with even greater force than to the carpenter, for there is so much in his work that requires taste and refinement, that to him hand-drawing and a proper cultivation of taste are absolutely indispensable. The Germans (amongst whom technical education has from early times been well attended to) imply this in the very names they give to the different departments of the workers in wood. They do not seem to consider the work of the house-carpenter to be merely making a good joint or planing wood very skilfully, and therefore do not use the term "joiner." They call the workman "Bau-tischler" (the *building*, *cabinet*, or *table maker*), and the "Fein-zimmermann" (the *fine-room man*); and these terms will at once be understood as conveying the meaning that from the joiner not only neatness but taste is required; and he cannot acquire this, or even cultivate that which may be (and in many cases *is*) natural to him, without patiently studying and practising the delineation of beautiful forms which Nature spreads so bountifully around, and which men of former periods have produced. The South Kensington Museum, a perfect art-world, contains innumerable specimens of the application of art to trade purposes, and the student is strongly urged to avail himself of the advantages of such an exhibition, and of the excellent tuition given in the numerous schools of science and art, spread not only over London, but throughout the provinces.

The object of introducing freehand drawing at this stage is that the student may practise it, little by little, as he progresses with his linear drawing, and so cultivate both branches equally. This will be found more satisfactory than allowing the study of ruling-work to outstrip hand-work; for, where this is the case, whilst the ruled lines may be exceedingly well done, the curved parts will be so clumsily added that the appearance of the drawing will be quite spoiled.

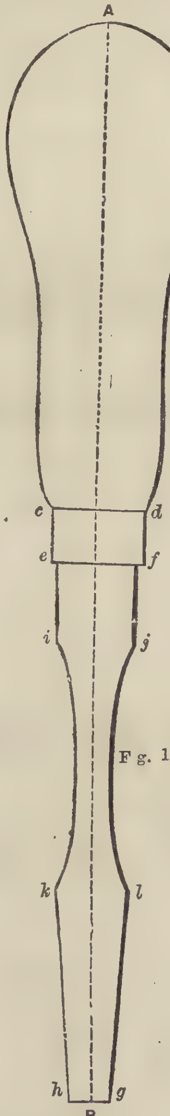


Fig. 10.

It is intended to introduce at a further stage the elements of ornamental forms; but in commencing, it is deemed best that the subjects should be such as are well known to the student. He will then be able to check his own work, for he will at once see whether his drawing is really like the tool he has in his basket; and I would hope that it may lead him to try to make drawings of others direct from the objects and unaided by copies.

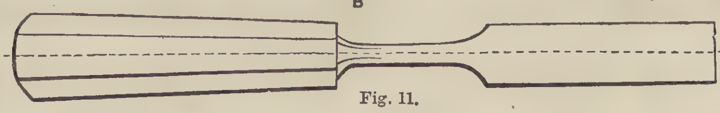


Fig. 11.

We commence, then, with Fig. 10, which is intended to represent a joiner's screwdriver; and this example, simple as it is, will afford excellent practice in a most important branch of the study—the balancing of parts.

Here the perpendicular, A B, is to be drawn first, and, when this is accomplished (by *hand*, not by means of the rule), proceed in the following manner:—

Draw the lines *c d* and *e f*, crossing A B at right angles; observing, but *not* measuring, the distance between them. Next draw the line *g h*, which is to form the edge of the blade; and also dot fine lines across at *i j* and *k l*.

All these lines are, in the first instance, to be drawn of indefinite length.

The two points to be observed are—

1. That they are at the proper distances apart.
2. That they are all really at right angles to A B.

Now mark off on each side of the central perpendicular the length of half the diameter of the brass ring, and draw the lines *c e* and *d f*.

The handle is to be drawn next, and this is formed of a continuous curve. Begin at A, and in the lightest manner possible sketch the curve extending to *c*. Adopt as a constant rule, that when two curves are to be balanced, it is advisable to draw the *left* side first, for if the right side were drawn before the other, you would most likely cover it with your hand whilst sketching the left; this would, of course, render your getting your two sides alike very difficult.

When, then, you feel in some degree satisfied that the left side of the handle is nearly correct, add the curve from A to *d*.

Observe.—There must not be a sharp point at A. The two sides must merge smoothly into each other at the top, so as to form one complete curve.

You can well imagine how very absurd a screwdriver would appear, and how very unfit it would be for work, if it had a sharp point at the top of the handle.

Now commence the blade, by drawing the perpendiculars *e i* and *f j*; then the curve *i k* on the left side, and *j l* on the right.

Mark off on *g h*, on each side of the perpendicular, half the width of the edge of the blade, and then draw the lines *kh* and *lg*, which will complete the form.

Now this will constitute the rough sketch. The next step is to convert it into a *drawing*. Pass your india-rubber lightly over the pencil lines, so as to remove as much lead as possible, without entirely erasing the form.

Fig. 11 is a sketch of a carpenter's chisel.

In beginning this, draw the central horizontal line, and across this draw the lines for the edge of the chisel, and the upper and lower ends of the handle.

Next draw the sides of the blade, which, differing from those of the screwdriver, are parallel to the central line. The lines for the edges of the handle are not, however, parallel, as the handle is wider at the upper than at the lower end.

Observe.—In using india-rubber, it is better to rub in the *direction of the lines* rather than *across* them; and when there is much lead upon the paper, it is better that the friction should be rapid and light rather than slow and hard. The rubbing should not be backward and forward, by which the lead rubbed off by one stroke is rubbed on again by the next; but the action should be like planing or filing—viz., in one direction, the rubber being raised in the backward motion.

The paper should at this stage present a perfectly clean appearance, with a very clear but slight trace of the form.

Now, with a fine, cleanly-cut point to your pencil, trace over the outline, avoiding all raggedness, and endeavouring to get each line of the same thickness throughout; those on the right side are to be rendered a little darker than the others. This process is called "lining in."

By following these directions closely, which are similar to those given for outline-work in the earlier "Lessons in Drawing" in The Popular Educator, and taking an example for practice from any tool that he may be in the constant habit of using, the beginner will soon find himself able to produce creditable drawings.

PRINCIPLES OF DESIGN.—I.

By Christopher Dresser, Ph.D., F.L.S., etc.

INTRODUCTION—VALUE OF ART-KNOWLEDGE—MEANING CONVEYED BY ANCIENT ORNAMENTATION.

At the very commencement of this series of articles on Ornamental Design, which I have undertaken to write at the request of the Editor of The Technical Educator, I desire to say that I address myself especially to working men, and that my sole object will be to teach what I consider useful to them. There are many handicrafts in which a knowledge of the true principles of ornamentation are almost essential to success, and there are few in which a knowledge of decorative laws cannot be utilised. The man who can form a bowl or a vase well is an artist, and so is the man who can make a beautiful chair or table. These are truths; but the converse of these facts is also true; for if a man be not an artist he cannot form an elegant bowl, nor make a beautiful chair.

At the very outset we must recognise the fact that the beautiful has a commercial or money value. We may even say that art may lend to an object a value greater than that of the material of which it consists, even when the object be formed of precious matter, as of rare marbles, scarce woods, or silver, or gold.

This being the case, it follows that the workman who can endow his productions with those qualities or beauties which give value to his works, must be more useful to his employer than the man who produces objects devoid of such beauty, and his time must be of higher value than that of his less skilful companion. If a man, who has been born and brought up as a "son of toil," has that laudable ambition which causes him to seek to rise above his fellows by fairly becoming their superior, I would say to him that I know of no means of his so readily doing so, as by his acquainting himself with the laws of beauty, and studying till he learns to perceive the difference between the beautiful and the ugly, the graceful and the deformed, the refined and the coarse. To perceive delicate beauties is not by any means an easy task to those who have not devoted themselves to the consideration of the beautiful for a long period of time, and of this be assured, that what now appears to you to be beautiful, you will shortly regard as less so, and what now fails to attract you, will ultimately become charming to your eye. In your study of the beautiful, do not be led away by the false judgment of ignorant persons who may suppose themselves possessed of good taste. It is very common to assume that women have better taste than men, and some women seem to consider themselves the possessors of even authoritative taste from which there can be no appeal. This may be the case, only we must be pardoned for not accepting such authority, for should there be any over-estimation of the accuracy of this good taste, serious loss of progress in art-judgment might result.

It may be taken as an invariable truth that knowledge, and knowledge alone, can enable us to form an accurate judgment respecting the beauty or want of beauty of an object, and he who has the greater knowledge of art can judge best of the ornamental qualities of an object. He who would judge rightly of art-works must have knowledge. Let him apply himself, then, to earnest study, for thereby he shall have wisdom, and by his wise reasonings he shall be led to perceive beauty, and thus have opened to him a new source of pleasure.

Art-knowledge is of value to the individual and to the country at large. To the individual it is riches and wealth, and to the nation it saves impoverishment. Take, for example, clay as a natural material: in the hands of one man this material becomes flower-pots, worth eighteen-pence a "cast" (a number varying from sixty to twelve according to size); in the hands of another it becomes a tazza, or a vase, worth five pounds, or perhaps fifty. It is the art which gives the value, and not the material. To the nation it saves impoverishment.

A wise policy induces a country to draw to itself all the wealth that it can, without parting with more of its natural material than is absolutely necessary. If for every pound of clay that a nation parts with, it can draw to itself that amount of gold which we value at five pounds sterling, it is obviously better thus to part with but little material and yet secure wealth, than it is to part with the material either in its native condition, or worked into coarse vessels, at a low rate, thereby rendering a great impoverishment of the native resources of the country necessary in order to its wealth.

Men of the lowest degree of intelligence can dig clay, iron, or copper, or quarry stone; but these materials, if bearing the impress of mind, are ennobled and rendered valuable, and the more strongly the material is marked with this ennobling impress the more valuable it becomes.

I must qualify my last statement, for there are possible cases in which the impress of mind may degrade rather than exalt, and take from rather than enhance, the value of a material. To ennoble, the mind must be noble; if debased, it can only debase. Let the mind be refined and pure, and the more fully it impresses itself upon a material, the more lovely does the material become, for thereby it has received the impress of refinement and purity; but if the mind be debased and impure, the more does the matter to which its nature is transmitted become degraded. Let me have a simple mass of clay as a candle-holder rather than the earthen candlestick which only

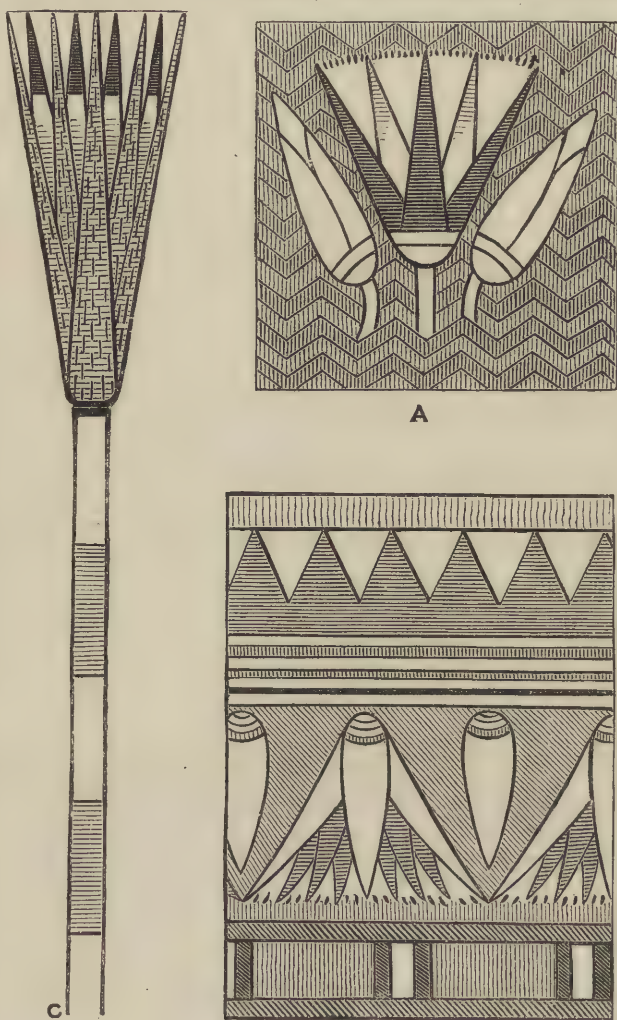


FIG. 1.—THE LOTUS (BLUE WATER-LILY) OF THE EGYPTIANS, AS CONVENTIONALLY TREATED BY THEM.

A. Open flower and bud on mummy-case. B. Flower and bud on border or cornice. C. Lotus flower and stalk.

presents such a form as is the natural outgoing of a degraded mind.

There is another reason why the material of which beautiful objects are formed should be of little intrinsic value, besides that arising out of a consideration of the exhaustion of the country, and this leads me to say that it is desirable in all cases to form beautiful objects of an inexpensive material as far as possible. Clay, wood, iron, stone, and copper are materials which may well be fashioned into beautiful forms; but beware of silver, and of gold, and of precious stones. The most fragile material often endures for a long period of time, while the almost incorrosible silver and gold rarely escape the ruthless hand of the destroyer. "Beautiful though gold and silver are, and worthy, even though they were the commonest of things, to be fashioned into the most exquisite devices, their money value makes them a perilous material for works of art. How many of the choicest relics of antiquity are lost to us, because they tempted the thief to steal them, and then to hide his theft by melting them! How many unique designs in gold and silver have the vicissitudes of war reduced in fierce haste into money-changers' nuggets! Where are Benvenuto Cellini's vases, Lorenzo Ghiberti's cups, or the silver lamps of Ghirlandajo? Gone almost as completely as Aaron's golden pot of manna, of which, for another reason than that which kept St. Paul silent, 'we cannot now speak particularly.' Nor is it only because this is a world 'where thieves break through and steal' that the fine gold becomes dim and the silver perishes. This, too, is a world where 'love is strong as death;' and what has not love—love of family, love of brother, love of child, love of lover—prompted man and woman to do with the costliest things, when they could be exchanged as mere bullion for the lives of those who were beloved?"* Workman! it is fortunate for us that the best vehicles for art are the least costly materials.

Having made these general remarks, I may explain to my readers what I am about to attempt in the series of papers which I have now commenced. My primary object will be the bringing about refinement of mind in all who may accompany me through my studies, so that they may individually be enabled to judge correctly of the nature of any decorated object, and enjoy its beauties—should it present any—and detect its faults, if such be present. This refinement I shall attempt to bring about by presenting to the mind considerations which it must digest and assimilate, so that its new formations, if I may thus speak, may be of knowledge. We shall carefully consider certain general principles, which are either common to all fine arts or govern the production or arrangement of ornamental forms. Then we shall notice the laws which regulate the combination of colours, and the application of colours to objects; after which we shall review our various art manufactures, and consider art as associated with the industrial arts. We shall thus be led to consider art furniture, earthenware, table and window glass, wall decorations, carpets, floor-cloths, window-hangings, dress fabrics, works in silver and gold, jewellery, hardware, and whatever is a combination of art with manufacture. I shall address myself, then, to the carpenter, the cabinet-maker, potter, glass-blower, paper-stainer, weaver and dyer, silversmith, jeweller, blacksmith, gas-finisher, mason, designer, and all who are in any way engaged in the production of art objects.

But before we commence our regular work, let me say that without laborious study no satisfactory progress can be made. Labour is the means whereby we raise ourselves above our fellows; labour is the means by which we arrive at affluence. Think not that there is a royal road to success—the road is through toil. Deceive not yourself with the idea that you are born a genius, that you were born an artist. If you are endowed with a love for art, remember that it is by labour alone that you can get that knowledge which will enable you to present your art ideas in a manner acceptable to refined and educated people. Be content, then, to labour. In the case of an individual, success appears to me to depend upon the time which he devotes to the study of that which he desires to master. One man works six hours a day; another works eighteen. One has three days in one; and what is the natural result? Simply this—that the one who works the eighteen hours progresses with three times the rapidity of the one who only works six hours. It is true that individuals differ in mental capacity, but my experience has led me to believe that those who work the hardest almost invariably succeed best.

While I write, I have in my mind's eye one or two on whom Nature appeared to have lavishly bestowed art gifts; yet these have made but little progress in life. I see, as it were, before me others who were less gifted by Nature, but who industriously persevered in their studies, and were content to labour for success; and these have achieved positions which the natural genius has failed even to approach. Workman! I am a worker, and a believer in the efficacy of work.

We will commence our systematic course by observing that good ornament, good decorations of any character, have qualities which appeal to the educated, but are silent to the ignorant, and that these qualities make utterance of interesting facts; but before we can rightly understand what I may term the hidden utterance of ornament, we must inquire into the general revelation which the ornament of any particular people, or of any historic age, makes to us, and also the utterances of individual forms.

As an illustration of my meaning, let us take the ornament produced by the Egyptians. In order to see this it may be necessary that we visit a museum—say the British Museum—where we search out the mummy-cases; but as most provincial museums boast one or more mummy-cases, we are almost certain to find in the leading county towns illustrations that will serve our present purpose. On a mummy-case you may find a singular ornament, which is a conventional drawing of the Egyptian lotus, or blue water-lily* (see Fig. 1), and in all probability you will find this ornamental device repeated over and over again on the one mummy-case. Notice this peculiarity of the drawing of this lotus—a peculiarity common to Egyptian ornaments—that there is a severity, a rigidity of line, a sort of sternness about it. This rigidity or severity of drawing is a great peculiarity or characteristic of Egyptian drawing. But mark! with this severity there is always coupled an amount of dignity, and in some cases this dignity is very apparent. Length of line, firmness of drawing, severity of form, and subtlety of curve, are the great characteristics of Egyptian ornamentation.

What does all this express? It expresses the character of the people who created the ornaments. The ornaments of the ancient Egyptians were all ordered by the priesthood, amongst whom the learning of these people was stored. The priests were the dictators to the people not only of religion, but of the forms which their ornaments were to assume. Mark, then, the expression of the severity of character and dignified bearing of the priesthood: in the very drawing of a simple flower we have presented to us the character of the men who brought about its production. But this is only what we are in the constant habit of witnessing. A man of knowledge writes with power and force; while the man of wavering opinions writes timidly and with feebleness. The force of the one character (which character has been made forcible by knowledge) and the weakness of the other is manifested by his written words. So it is with ornaments: power or feebleness of character is manifest by the forms produced.

The Egyptians were a severe people: they were hard task-masters. When a great work had to be performed, a number of slaves were selected for the work, and a portion of food allotted to each, which was to last till the work was completed; and if the work was not finished when the food was consumed, the slaves perished. We do not wonder at the severity of Egyptian drawing. But they were a noble people—noble in knowledge of the arts, noble in the erection of vast and massive buildings, noble in the greatness of their power. Hence we have nobility of drawing—power and dignity mingled with severity in every ornamental form which they produced.

We have thus noticed the general utterance or expression of Egyptian drawing; but what specific communication does this particular lotus make? Most of the ornaments of the Egyptians—whether the adornments of sarcophagi, of water-vessels, or mere charms to be worn pendent from the neck—were symbols of some truth or dogma inculcated by the priests. Hence Egyptian ornament is said to be symbolic.

* From a lecture by the late Professor George Wilson, of Edinburgh.

* This can be seen growing in the water-tanks in the Kew Gardens' conservatories and in the Crystal Palace at Sydenham

The fertility of the Nile valley was chiefly due to the river annually overflowing its banks. In spreading over the land, the water carried with it a quantity of rich alluvial earth, which gave fecundity to the country on which it was deposited. When the water which had overspread the surrounding land had nearly subsided, the corn which was to produce the harvest was set by being cast upon the retiring water, through which it sank into the rich alluvial earth. The water being now well-nigh within the river-banks, the first flower that sprang up was the lotus. This flower was to the Egyptians the harbinger of coming plenty, for it symbolised the springing forth of the wheat. It was the first flower of spring, or their primrose (first rose). The priesthood, perceiving the interest with which this flower was viewed, and the watchfulness manifested for its appearance, taught that in it abode a god, and that it must be worshipped. The acknowledgment of this flower as a fit and primary object of worship caused it to be delineated on the mummy-cases, and sarcophagi, and on all sacred edifices.

We shall have frequent occasion, while considering decorative art, to notice symbolic forms; but we must not forget the fact that all good ornaments make utterance. Let us in all cases, when beholding them, give ear to their teachings!

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

II.—SIR HUMPHRY DAVY.

BY JAMES GRANT.

Sir Humphry Davy, Bart., LL.D., F.R.S., Member of the Foreign Institute of France, the eminent chemical analyst and discoverer, and inventor of the famous safety lamp, was the eldest of the four children of Robert and Grace Davy, and was born in the old municipal borough of Penzance, in Cornwall, on the shore of Mounts Bay, on the 17th of December, 1778. In the adjacent parish of Ludgvan his ancestors had long possessed the estate of Varfell, and there he resided in his earlier days. In the church are several tablets of the family, and one bears the date 1635. A strong and healthy child, he walked at nine months old; and at two years of age he could speak with fluency, and accurately recite stories and copy the figures from "Æsop's Fables." He was taught reading and writing by a Mr. Bushell, and was then sent to Truro Grammar School, under Dr. Cardew, where he was chiefly famous among the pupils as a narrator of tales and stories, especially from the "Arabian Nights." Much of his enthusiasm for the poetic and the marvellous was fed by the grand scenery of his native county, and the traditions of giants and hobgoblins with which local superstition still peoples it.

His quitting Dr. Cardew's school in 1798 was an important era in his life. At fifteen his school education was deemed complete; thus to his future self-education he owed all. In the following year his father died, an event which gave a steadfastness to all his resolutions. In 1795 he was apprenticed to Mr. Bingham Barlow, then surgeon and apothecary in Penzance, and in after years a distinguished physician. Young Davy's note-books show the ardour with which he entered on his new career, during which he published some poems of considerable merit in the "Annual Anthology." In 1797 he was working hard at Euclid and algebra, and was deep in the study of Locke, Hartley, and Helvetius, together with the writings of Reid, Hume, and others, who are designated by him as "the Scottish metaphysicians." The house in which he passed the years of his apprenticeship has recently been removed to make way for the Town Hall.

He now commenced in earnest the study of natural philosophy, and went more deeply into chemistry on the system of Lavoisier, and at the same time he became a skilful draughtsman. In 1798 he began to form those peculiar views respecting heat and light, in opposition to those then commonly received; and on this subject corresponded with Dr. Beddoes, who became a convert to his principle. Among his earliest researches at Penzance are those on the respiration of fishes and of zoophytes, in which he maintains that oxygen is essential to the existence of those classes of animals; that they breathe the air contained in the water, and, like the higher class of land animals, convert the oxygen by the addition of carbon, into carbonic acid gas. In October that year, before he was twenty-one years of age, he left home to enter on a new and enlarged sphere of existence—a public career in the Pneumatic Institution at Clifton—where, however, he was only two years and a half, when, at the suggestion of Count Rumford, he was appointed Professor of Chemistry in the Royal Institution of Great Britain; and then he completed and gave to the world his first views of heat and light. At this time his chief friends and correspondents were Southey and Gregory Watt (son of the famous James Watt), whose acquaintance he had made when the latter was travelling in Cornwall for the benefit of his health; but he soon found other intimate friends and colleagues in Herschel, Dalton, Wollaston, Cavendish, Knight, Warburton, and Allen. His success as a lecturer was most eminent, and the theatre—capable of holding a thousand persons—was always crowded to excess when he appeared. The best specimen of his powers is supposed to be contained in a lecture on electro-chemical science, delivered on the 12th of March, 1808, in which, after Bacon, he vindicated the benefits accruing to mankind from experimental science and natural knowledge in general, against all *cui bono* carpers.

This was to him a happy period of his life: enjoying the best society in London as only a young man can enjoy it, and when his duties set him free, travelling to the wildest parts of Scotland, Ireland, and Wales as a geologist and angler, returning always with numerous specimens, which now remain in the museum of the Royal Institution. But amid all his occupations he never forgot his Cornish home, and to write a New Year's letter to his mother, with regular Christmas-boxes of "ten shillings to Betty White and ten shillings to Mary Lander," her old servants, as his published correspondence shows. The years 1806 and 1807 saw him immersed in the study of the use of electro-chemical science, and the extreme delight he felt when he first saw the metallic basis of potash can only be conceived by those who are familiar with the operations of the laboratory, and the exciting nature of original research; but illness, the result of over-work, came upon him now—an illness consequent, as some supposed, on a visit he had paid Newgate for the purpose of inquiring into the sanitary condition of that great and then foul prison. For a time he feared it would prove fatal, and his greatest apprehension was that he should die before he had given his discoveries to the world. After the 23rd of November—he was nine weeks ill—he was convalescent, and during that period he again amused and solaced himself by writing verses, a species of amusement to which he had occasional recourse during his life-time. His friend Beddoes died on Christmas Day, 1807, and on that occasion Davy wrote a touching letter to their friend Coleridge, saying that "he had gone at the moment when his mind was purified and exalted for noble affections and great works. My heart is heavy."

In 1810 and 1811 he visited Dublin, where he met with a most enthusiastic reception, and the degree of D.C.L. was conferred upon him by Trinity College. He received 1,150 guineas for two lectures, and it was then that Cuvier wrote of him as—"Davy, not yet thirty-two, in the opinion of all who can judge of such labours, holds the first rank among the chemists of this or any other age."

After his marriage with Mrs. Apreece, in 1812, he wrote of her with enthusiasm to his brother John as "a noble creature who every day added to his contentment by the powers of her understanding and delightful tones of feeling;" and to her he dedicated his "Elements of Chemical Philosophy." In 1814 he was in Italy, and his researches while there appeared in the "Philosophical Transactions" of the Royal Society for that year. He studied deeply all the marine productions of the shores of the Mediterranean; and in a letter to his brother says of this tour, "I have lived much with Berthollet, Cuvier, Chaptal, Vauquelin, Humboldt, Morveau, Clement, Chevreul, and Gay Lussac, and they were all kind and attentive to me." At Florence and Rome he entered upon a new subject of inquiry—the nature of the diamond, and discovered that it was merely crystallised carbon. He also mentions that he saw old Pius VIII. carried in triumph into the Eternal City on the shoulders of the most distinguished artists, one of whom was Canova. In 1818 he was created a baronet.

At Milan in 1814 he visited Volta (the inventor of the Voltaic battery), then in his seventieth year. From thence he crossed the Alps by the Simplon; and wherever he wandered in Italy

he was never idle—the laboratory, the flora, and the study of antiquities affording him incessant occupation. His observations on the fast colours used in painting by the ancients, experiments on the solid compound of iodine and oxygen, and the action of acids on salt—usually called hyper-oxymuriates—and the gases produced from them, all appeared in the papers of the Royal Society in quick succession. In March he visited Vesuvius, and gave an interesting sketch of the visible strata.

While travelling in the Tyrol he made the acquaintance of the old mountain patriot, Speckbacker, who oddly enough presented him with the identical musket with which he shot thirty Bavarian soldiers in one day; this trophy Davy afterwards presented to his friend Scott, and it is now preserved in the armoury at Abbotsford. May found him and Lady Davy in London, when he entered on a new train of inquiry, the investigation of fire-damp, with a view to the more efficient protection of mines and also of the workmen who are exposed to its destructive agency—objects of vast importance in regard to the interests of humanity, and which were ultimately accomplished by his famous invention of the safety lamp, which was calculated, as his paper stated, "for preventing explosion in mines, houses lighted by gas, spirit warehouses, and ship-magazines." In 1815 he gave his entire attention to this important subject. After reasoning on all the various phenomena and causes of fire-damp, "it occurred to me," he continues, "as a considerable heat was required for the inflammation of the fire-damp, and as it is produced by the burning of a comparatively small degree of heat, that the effect of carbonic acid and azote, and of the surfaces of small tubes in preventing its explosion, depended upon their cooling powers, and upon their lowering the temperature of the exploding mixture so much that it was no longer sufficient for its continuous inflammation." His safety lamp was simply a cage of wire-gauze, which actually made prisoner the flame of the fire-damp; and whilst it confined the dangerous and explosive flame (consuming it at the same time), permitted the air to pass and the light to escape; and though, from the combustion of the fire-damp, the cage might become red-hot, yet it acted the part of a safety lamp, and restrained the flaming element within its narrow bounds: hence the imprisoned flame was not capable of rising high enough to explode with the fire-damp without, or to allow the flame kindled within to pass unextinguished. Letters now poured in upon him from proprietors of mines and collieries, expressing their gratitude for his invention. A public banquet, presided over by the future Earl of Durham, was given to him at Newcastle, and he was presented with a service of plate valued at £2,500. The year 1817 saw his researches on the subject of fire-damp brought to a close; and after visiting Orkney, he departed on a second Continental tour through Austria, Hungary, Vienna, along the shores of the Adriatic, and thence again to Rome. Of this journey he left an interesting journal, and during it made experiments on the papyri found in the ruins of Herculaneum, which he published together with some observations on volcanoes, having witnessed the eruptions of Vesuvius in 1819 and 1820.

On the death of Sir Joseph Banks, in the latter year, he became president of the Royal Society—an office held by his predecessor for forty-two years. He continued his scientific labours, especially on magnetism, the liquefaction of gases, and researches into the corrosion and protection of the copper sheathing of vessels. In 1824 he made a tour through Scandinavia, Holstein, and Hanover, travelling more than 2,000 miles. He was graciously received by the Crown Prince of Sweden, and at dinner sat on the left of the princess—the grand-daughter of the Empress Josephine. At Altona—of which Blucher was then governor—he visited the tomb of Klopstock. The following year found him rusticating amid the beautiful scenery of Westmoreland. But 1826 saw his health breaking, indisposition creeping upon him, rheumatism impeding his literary labours; and then the death of his mother, to whom he was tenderly attached, gave him a severe mental shock that was soon afterwards followed by a bodily one. At the meeting of the Royal Society on St. Andrew's Day, it was evident to all that his discourse was delivered by a great effort; and fourteen days after, his whole left side was affected by paralysis, which came on him suddenly when shooting with Lord Gage. He immediately sought the aid of his friend Dr. Babington; but in this prostrate condition actually corrected the proofs of his "Discourses," which were published in quarto in 1827. The 22nd of January saw him so far recovered as to be able once more to seek the Continent. He crossed France and Mont Cenis to Italy, and by the kindness of the Vice-Legate was lodged in the Apostolic Palace at Ravenna, where he resumed his journal, his diary, and wrote several poems of great sweetness and pathos; but came home more than ever broken in health. Again he sought the Continent, visiting Austria, Flanders, thence to the Noric Alps, Styria, and Trieste, that, ailing as he was, he might test the experiments he had long been meditating on the torpedo, and on returning to Laybach he communicated his views to the society. May, 1829, saw him at Geneva, where he took up his residence at the Hotel la Couronne. At five o'clock on the 28th he dined as usual, and at nine o'clock accidentally struck an elbow against a sofa. The effect was extraordinary; a universal tremor passed over his frame, and he exclaimed that he was "dying." He was put to bed as soon as possible, but gradually sank into a state of insensibility, and expired at three o'clock in the morning of the 29th; his eyes being closed by his faithful brother John. On the 1st of June his remains were deposited in the burying-ground without the walls, and close to those of Professor Pictet, where Lady Davy afterwards erected a tomb with a suitable inscription in Latin. No post-mortem examination was made, as he had throughout his life shown a nervous horror of such searches. By his will he bequeathed to the grammar school of his native town £100, "on condition that the boys were to be allowed an annual holiday on his birthday."

Thus, at the early age of fifty-one, passed away one of the brightest luminaries and best men in the world of science; a mere enumeration of whose writings would go far beyond our limits.

AGRICULTURAL CHEMISTRY.—II.

BY CHARLES A. CAMERON, M.D., PH.D.

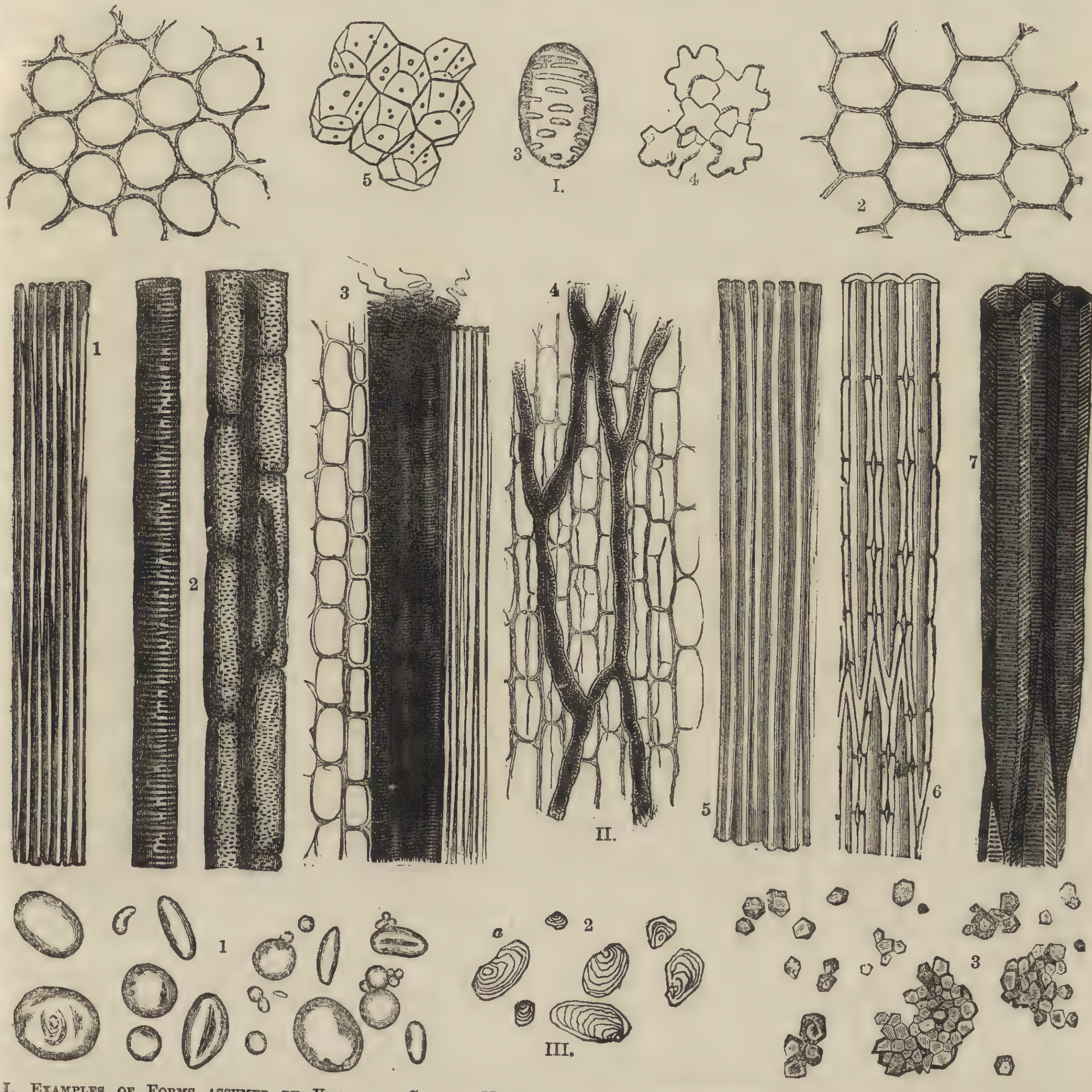
CHAPTER II.—THE ELEMENTARY PARTS OF PLANTS.

THE almost infinite variety of form, colour, weight, and every other attribute of the multitudinous objects in the vast storehouse of Nature, naturally suggests to most minds the idea that the number of raw materials from which they have been elaborated must necessarily be very great. We have, however, shown in a previous chapter that such is not the case, and that the number of first principles is very small. A mass of any one of these first principles or elements is, there is good reason to suppose, an aggregation of minute particles, which, from a belief in their indivisibility by chemical or physical means, are termed *atoms*.* In a strictly mathematical sense we cannot consider atoms to be indivisible, because matter, however minute in quantity, possesses weight, length, breadth, thickness, and extension. An atom, however, may be regarded as an aggregation of innumerable smaller particles, which cannot be separated from each other, at least by any power at man's disposal. The Greek philosopher, Democritus, by an ingenious illustration exhibited intelligibly the impossibility of dividing an atom. He likened the matter of which our earth is composed to the starry firmament, each member of which being so small compared with its distance from the others and the immensity of the universe, may really be termed an atom; for although it is composed of a number of particles of matter, yet all these particles are bound together by a force which no external influence can affect. Neither can its form or its distance from the other heavenly bodies be altered. From this point of view the universe may be regarded as a vast aggregation of indivisible and unchangeable atoms.

As in the inanimate the apparently insignificant atom is believed to play the most important part, so in the animate creations we find the essential functions of life discharged in those parts of animals and plants which are apparently so low in the scale of organisation as to be all but unworthy of our attention. Animate as well as inanimate matter is composed of small and, in a physiological sense, indivisible atoms. As an amorphous (uncrystalline) mass of mineral matter possesses

* From the Greek words, *a*, a privative particle, and *temno*, I cut.

only the properties which distinguish a single atom of it, so also are there immense masses of living matter (simple cellular plants) composed of *organic atoms*, each of which possesses all the properties which we recognise in their aggregated unity. And again, as the grouping of atoms of a particular kind of substance—say carbon—into crystalline masses causes them



I. Examples of Forms assumed by Vegetable Cells. II. Examples of Forms assumed by Woody Fibre. III. Examples of Forms assumed by Starch Granules.

Ref. to Nos. in Figs.—I. 1, circular vegetable cells; 2, polyhedral form induced by compression; 3, ovoid or spheroid cell; 4, stelliform cells; 5, angular cells. II. 1, woody fibre magnified; 2, striated and punctated vessels of melon; 3, spiral fibres or tracheæ of plants; 4, lactiferous vessels of celandine; 5, librine fibres of hemp; 6, woody fibre of the fir; 7, scalariform vessels of the tree-fern. III. 1, arrowroot starch; 2, wheat starch; 3, rice starch.

to acquire in combination properties which individually they did not possess, so the various arrangements of atoms of organic matter give rise to structures which manifest properties unrecognised in the simple atom.

The organic atom is simply the *nucleated* cell of the vegetable physiologist. Its external configuration is probably similar to that of the mineral atom, and as the latter gains in weight at least in different inanimate substances, so does the former vary in size in different animate bodies. Although there are numerous points of resemblance between the two classes of atoms, there is believed to be this important difference—the inorganic atom is conceived homogeneous, whereas the atoms of organised structures are, so to speak, heterogeneous. But certain botanical microscopists affirm that the cell takes its origin from an exceedingly minute and homogeneous particle of spherical form, which they have termed the *cell germ*. It is, however, not probable that this germ is the ultimate atom of vegetable substances, inasmuch as it is easily visible through the microscope, whilst the same instrument reveals the existence of plants so minute that hundreds of millions occupy the limited space of one cubic inch without interfering with each other! As each of these minute organisms must be composed of numerous parts or atoms, excessive minuteness of the latter presents an impassable barrier to all save speculative inquiries

relative to their size and form. The cell may, therefore, for the purposes of research, be regarded as the elementary organ or atom of organised structures.

The cell consists of a little bladder formed by an elastic transparent and extremely thin membrane. The cavity contains semi-liquid and sometimes gaseous matters. The wall of the cell is apparently devoid of definite structure; it is composed chiefly of *cellulose*, a substance resembling starch in composition. On the inner side of the cell there is a thick, mucilage-like substance, termed *protoplasm* or *formative layer*. In the cell there is a small spherical, termed the nucleus, which closely invests a smaller body—according to some, a cavity—called the *nucleolus*. The nucleus and the protoplasm are destined to form into new cells.

The shape of cells is influenced by the condition under which they are developed. When their growth is unopposed, or when they are exposed only to gentle and equable pressure, their form is most frequently that of a sphere or spheroid. Owing to unequal pressure, cells, however, are found to present a great variety of forms, many being tube-like. The engraving in the preceding page (Fig. I.) exhibits the varied forms assumed by cells.

Wood is in great part composed of tube-like cells. When the tubes are very long and narrow, they are termed *vessels*. Cells vary much in size; sometimes they are easily recognisable by the unassisted eye; but in general they are at least only the one-thousandth of an inch in diameter.

In the lowest forms of vegetable life the cells are all but unconnected, and all perform the same functions; but in the higher forms of plants they coalesce and form structures, each of which discharges a different function in the economy of the plant. The least organised plants are termed *cellulars*. In these lowly forms of vegetable life the cells touch, each at a limited number of points, forming intermediate spaces, termed *intercellular canals* or *passages*. *Compact tissue* is produced when the cells lie close together. In the higher plants there are both *loose* and *compact* tissue. The majority of physiologists believe that there are numerous minute pores in the cell-walls; a very probable hypothesis, for otherwise it would be difficult to account for the fact that gases and liquids pass through the cell-walls.

The important food substances, starch and albuminoid bodies, are found in cells. The former, according to Mulder, is composed of nuclei, in which matter destined for the nutrition of the offspring of the plant is stored up. The engraving (Fig. III.) represents the various appearance of some of the starch granules contained in cells. In the cells we also find the matter termed *chlorophyll*,* which confers upon plants their green colour. The circulation of the juices of the plant is carried on by means of the cellular tissue, and in thousands of species the circulation is solely carried on through this agency. Owing to the looseness of the cellular tissue, and to the tenacity of the individual cells, these structures render plants strong and elastic at the same time.

The substance of which cell tissue is formed is supposed to consist of extremely minute round bodies placed side by side, leaving very minute spaces between them. In young cells the tissue or membrane is extremely thin, and is translucent; but after a time it generally becomes thicker and more opaque. Chemically, the membrane is composed of carbon, hydrogen, and oxygen, and is almost identical in composition with starch. By chemical treatment it is readily converted into a species of sugar. In certain parts of numerous plants the cell-wall is lined with a very hard substance, termed *sclerogen*, which appears to be almost, if not quite, identical in composition with the cell-wall. The hardness of various kinds of nuts is due to the sclerogen in their cellular tissue. The hardness of wood is in great part due to the sclerogen or lignine contained in its cells. Cellulose occurs nearly pure in elder pith, cotton, and linen. It constituted the celebrated *papyrus* or paper so extensively employed by the ancient Egyptians and Greeks. Examples of varieties of plant-fibre are given in Fig. II. in the preceding page.

Elementary fibre is identical in composition with elementary membrane, on the side of which it is deposited from the protoplasm. It is solid, body generally rounded, and almost always translucent or transparent. Its function is to sustain the elementary membrane, and to prevent any of its folds from coming into actual contact with each other. In *fibro*-cellular tissue we find cells having one or several fibres wound in a spiral direction round its inner side. As the sides of cells containing fibres are kept well apart, they are generally found to contain air.

Woody fibre consists of long tubes (formed from cells) having tapering extremities; their ends overlap each other. They are more or less filled with sclerogen or lignine. This kind of tissue is particularly abundant in forest trees.

Vascular tissue is found only in the higher forms of vegetable life. It consists of long unbranched tubes or ducts, which, however, are only a series of cells opening into each other. These tubes are believed to be chiefly employed in conveying air throughout the vegetable mechanism, and they may be regarded as somewhat analogous to the lungs of animals. Woody tissue is a species of vascular tissue, and so also are the branched tubes termed lactiferous vessels, in which the milk-like liquid found in certain plants is contained.

* From the Greek *chloros*, green, and *phyllon*, a leaf.

MINERAL COMMERCIAL PRODUCTS.—III.

LEAD.

THIS metal, the heaviest of the baser metals (sp. gr. 11·45), is soft, easily fused, and very slightly sonorous. It is largely used in roofing, lining, plumbing, and bullet and shot making. It also enters into the composition of pewter, solder, and type-metal; and in its chemical combinations it forms litharge (the oxide), a yellow paint; red lead (red oxide), a cheap substitute for vermilion; white lead (carbonate), manufactured on an immense scale for the painter; and sugar of lead (the acetate), of great value to the chemist. These substances are highly poisonous.

The most abundant and important of the ores of lead is *galena*, a sulphide of the metal, yielding 86 per cent. of lead, and almost always containing silver, which is separated when the quantity is not less than four ounces to the ton. The other ores are: the *carbonate of lead*, the *vanadiate of lead*, the *cupreous sulphate of lead*, and the *arsenio-phosphate of lead*. Galena is found very abundantly in the limestones of the Carboniferous series, and to a less extent in older rocks. Its reduction is effected by pounding, washing, and smelting in a reverberatory furnace. Lead-mining is carried on in Britain (Northumberland, Cumberland, Durham, Derbyshire, Flintshire, Cornwall, Isle of Man, and Lead-hills), also in Spain and Portugal, France, Belgium, the Harz Mountains, Saxony, Rhine Provinces, Bohemia, Carinthia, Hungary, Norway, and Sweden; Altaï Mountains, China, and Indo-Chinese Peninsula, South Africa, Peru, California, United States, and Canada.

The annual supply of lead from the different countries of Europe is—

	Tons.		Tons.
Britain	67,000	Spain	313,000
Austria (with litharge)	6,800	Sweden	500
Zollverein	38,800	France (metriquintals)	20,000

ZINC.

This metal, of a bluish-white colour, and specific gravity about 7, has the remarkable peculiarity of being malleable and ductile only between the temperatures of about 250° and 300° Fahr., and of retaining its malleability when cooled. It forms a cheap substitute for many of the applications of lead, such as tanks, pipes, roofs, and for bronze in ornamental works. It enters into the composition of brass, and is now extensively employed in domestic manufactures, printing, engraving, sheathing of ships, coating of galvanised iron, electrical apparatus, and medicine. Its oxides form valuable white and grey paints.

The principal ores of zinc are, *calamine*, a carbonate (ZnO,CO_2); *blende* or *blackjack*, a sulphide; and a silicate, or *electric calamine*. They occur often in association with the ores of lead, and frequently with the ores of copper and tin, chiefly in limestones of the Carboniferous and Devonian systems. The pure metal is obtained by roasting and distillation, as it is very volatile at a red heat. The ores are largely worked in Belgium, Silesia, Rhine Provinces, and Hungary. Zinc is also produced

in Flintshire, Derbyshire, Cumberland, Cornwall, Devon, Ireland, Wales, Isle of Man, Sweden, Bohemia, Carinthia, Spain, the Harz, Canada, New Hampshire, and New Jersey, in which last place the metal occurs in the mineral red zinc ore, an oxide of zinc.

The average annual production of zinc from Europe and the United States is:—

	Tons.		Tons.
Britain	4,460	Sweden (ore)	10,000
Silesia	36,000	Zollverein	76,000
Austria	1,500	Belgium	16,000
Spain	1,000	United States	5,000

ALUMINUM.

This metal is white, resembling silver, and is of low specific gravity (2·6). It exists abundantly in Nature as the metallic base of argillaceous and felspathic rocks, which are silicates of alumina, and as sulphate of alumina, an important constituent of the alums. The pure metal has lately been obtained in quantities available for manufacturing purposes; and from its extreme lightness, its freedom from tarnishing, and its sonorousness, it promises to become a most useful product. The metal can be separated from the earth alumina, or from the chloride; but it is obtained economically only from *Cryolite*, a double fluoride of aluminum and sodium, found in Greenland.

ANTIMONY.

Antimony is white and brittle, with a specific gravity of 6·8. As a simple metal it is not used, but it forms valuable alloys. With lead and bismuth it is largely used in the preparation of type-metal, which consists of 6 parts of lead and 2 of antimony; with lead and tin for plates on which music is engraved, and with the same for stereotype metal. A small proportion of antimony combined with tin forms hard pewter; and with tin, bismuth, and copper, the white or Britannia metal. It is also very extensively employed in medicine. It occasionally occurs in a pure state, but usually combined with sulphur, or sulphur and lead; it is also found in combination with arsenic, and with nickel, silver, and copper.

Grey antimony, a tersulphide, affords nearly all the antimony of commerce. It is found in Hungary, Saxony, and the Harz, Belgium, France, Italy, Spain, Siberia, Mexico, Malacca, the Indian Archipelago, and was at one period produced in considerable quantities in Cornwall and Dumfriesshire; but now the principal part of our supply of antimony is from Borneo and the East Indies.

Central Italy furnishes 700 tons; Spain, 58 tons.

BISMUTH.

Bismuth is a brittle reddish-white metal (sp. gr. 9·9) which fuses at a very low temperature. It fuses still lower in combination with lead and tin, with which it is used as a solder, and with which it also forms the metal called "Newton's," fusible at the boiling-point of water. It enters, too, into the composition of Britannia metal, pewter, and type-metal, and is of some use in medicine. It is found, tolerably pure, usually associated with ores of tin, copper, and silver, in Cornwall, France, Bohemia, Saxony, and Sweden.

COBALT.

Cobalt is a white, brittle, and very tenacious metal. Its specific gravity is 8·5, and it is strongly magnetic. It is very useful in its chemical preparations as producing fine colouring substances, chiefly blue, such as smalts, cobalt-ultramarine, and zaffra or saflor (a corruption from sapphire). The principal ores are cobalt-glance, a combination with arsenic, the black oxide, and cobalt-bloom; they are found in Norway and Sweden, Saxony, Hungary, Rhenish Prussia, and the United States. The annual yield of zaffre or smalt amounts to, in Saxony, 8,000 cwt.; Bohemia, 4,000 cwt.; Prussia, 600 cwt.; Norway, 4,000 cwt.

NICKEL.

This metal is also found combined with arsenic. It is white, malleable, and but slightly affected by air and moisture. Its specific gravity is 8·5, and it is magnetic until subjected to great heat. With copper it forms German silver, and its alloys form excellent bases for electro-plating. A fine green colour is obtained from its preparations. Nickel has been used in the United States for coin. Its chief ore, "kupfer-nickel" or speiss, often associated with cobalt, is found in Westphalia, Saxony, Hesse, Hungary, and Sweden. Nickel occurs in meteoric iron.

ARSENIC.

Metallic arsenic is grey, highly lustrous, crystalline, and brittle (sp. gr. 5·7). The arsenic of medicine is the white oxide, or arsenious acid, a virulent poison; this is also largely employed in preparing some of the finer skins and furs of Russia. This metal enters into the composition of some valuable pigments, especially a brilliant green and an orange red. It is also combined with lead in the manufacture of shot. Arsenic is rather widely diffused; and although sometimes pure, it is usually found combined with other metals, with sulphur, and with oxygen. The chief amount is obtained from the arsenides of iron, nickel, and cobalt, and the supply is chiefly derived from Bohemia, Hungary, Saxony, Salzburg, Transylvania, Rhine Provinces, and France. *Realgar*, a red sulphide (AsS_2), is found in Bohemia and Saxony; and *orpiment*, another sulphide (AsS_3), a fine yellow, in China and South America.

Arsenic is also procured from the tin mines of Cornwall; the produce of the metal from this source for 1866 being $1{,}116\frac{3}{4}$ tons.

MANGANESE.

Manganese oxidises at ordinary temperatures, and is never used in the arts in the pure state. It is of a reddish hue, brittle, so hard as to scratch glass, and has a specific gravity of 7·13. The binoxide (MnO_2) is an important article of commerce, largely employed in glass manufacture and for colouring pottery, and by the chemist in the preparation of oxygen. Sulphate and chloride of manganese are used in calico printing; the former gives a valuable brown dye. It is found that a slight addition of this metal much improves the cast steel made from British iron. The principal ores of manganese are *Pyrolusite* and *Psilomelane*, both binoxides, the former anhydrous, the latter containing 1 per cent. of water. *Wad*, an impure manganese ore, may be employed, like the preceding, in bleaching, and also for umber paint. Manganese ores are procured from the Harz Mountains, Piedmont, France, Spain, Nova Scotia, Somerset, Devon, Isle of Man, and were formerly obtained from Cornwall, Italy, etc. Britain produces 5,000 tons.

CHROMIUM.

This metal, in its pure state brittle, difficult of fusion, and like iron in colour, is important in the arts for the beautiful colours produced by its combinations. The most important of these are the sesquioxide of chromium, a fine green, bichromate of potash, and bichromate of lead, yellow and orange. The principal ores are chromic iron (chromate of iron) and chromate of lead, the former occurring usually in serpentine rocks in the Shetland Isles, France, Norway, and the United States, and the latter in Siberia, the Urals, and Brazil.

TECHNICAL DRAWING.—IV.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

RETURNING now to the practice of drawing by means of instruments, a useful series of examples is here given for the student's use.

The subject of which Fig. 12 is the plan and Fig. 13 the section, is a network platform for a foundation where the soil is of a soft character, and liable to be pressed outward by the weight resting upon it, but still not sufficiently so to render absolute sheet-piling necessary. Strong piles (*c c c c*) are driven down to the firm soil, and these are connected by horizontal planks (*e e*), placed on each side and bolted through the piles.

Now in the space left between these planks a wall is formed of timbers, *d d d d*, which are driven down by hand-ramming, not extending downward further than the circumstances may render necessary.

These planks are jointed in various ways, with some of which you will become acquainted in the study of "Building Construction;" Fig. 14, rebated; Fig. 15, splayed at one edge and recessed at the other; Fig. 16, ploughed and tongued. In the example, the tongue is shown square and tapered, and in Fig. 17 it is worked in the dovetail form, whilst Fig. 18 shows the planks joined by an inserted tongue.

Now, to draw this series of examples—

First draw the piles, *c c c c* (Fig. 12), and continue the lines forming the edges of them, so that these may give you the sides of the piles shown in the section (Fig. 13).

Next draw the top of the wall of planks between the piles, and in the example it will be seen these are one-third the thickness of the piles; therefore, divide the edge of one of the piles on each side into three equal parts, and use the middle division for the thickness of the wall. This thickness, again, projected upwards, will give the elevation of the edge of the planks (*d d*). Now outside and inside of the piles draw the tying-planks, *e e e e*, and project them on to Fig. 13, *e e e e*, where it will be evident they will appear as sections.

Next draw the lower course of sleepers, *a a a a a*, and the elevation of them shown at *a*, in Fig. 13; then follow in their order the upper course of sleepers (*b b b b*), their projection in section (*b b b b*), and in these last the flooring of the platform which has not been shown in the plan.

The difference in the form of the piles when used separately, or at angles of foundations, and those called sheet-piles, will be fully described when treating of the principles of foundation in "Building Construction." The cuts (Figs. 19, 20, 21, and 22) are here introduced in order that they may be used as studies for drawing and shading. It may, however, be well to inform you that the points of the single or corner piles (Fig. 19) are four-square, whilst those of sheet-piles are only bevelled from *two* sides, and the edge is cut so as to slant downwards (Fig. 20).

Piles are generally worked of square timber, and if the trees admit of it, those which are to be rammed entirely into the ground are mostly slightly tapered downwards throughout their whole length, and are shod with iron at their points (unless the piles be small and the ground not very hard); and an iron ring is placed around the upper end, to prevent the piles from splitting by the violence of the blows necessary to force them down.

Sometimes, however, the piles which are to be driven quite below ground may be used without squaring; two illustrations of such (Figs. 21 and 22) are here given, to afford practice in shading cylindrical bodies.

Having pencilled and inked the outlines of the four piles shown in the example, wash over the part representing wood

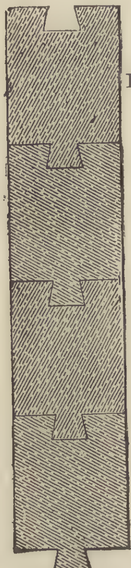


Fig. 17.

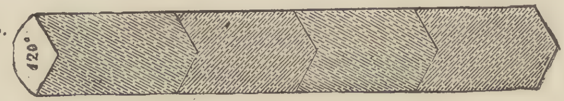


Fig. 15.

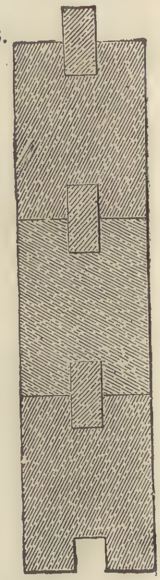


Fig. 18.

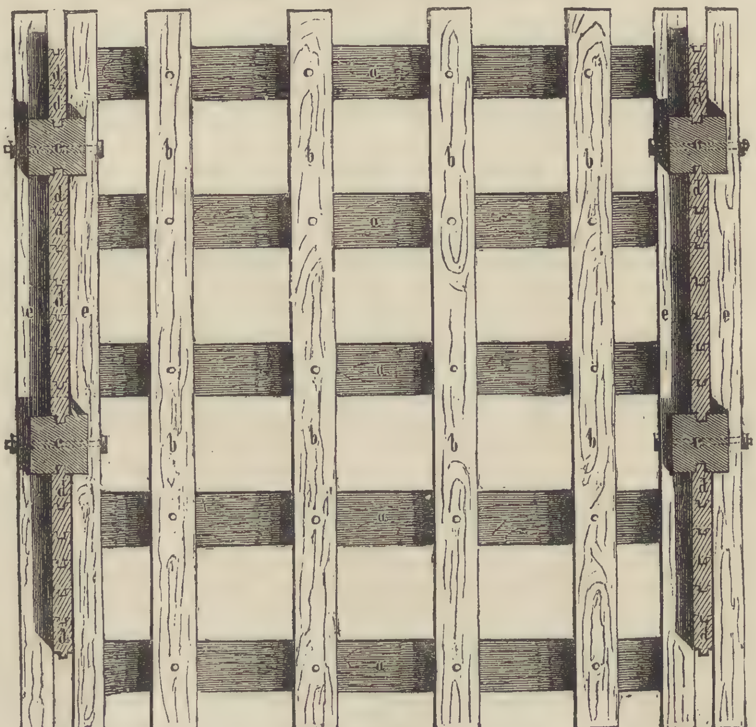


Fig. 12.

Fig. 16.

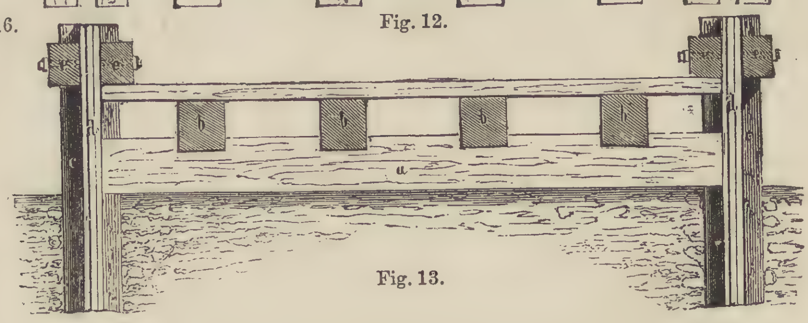


Fig. 13.

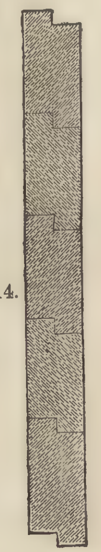


Fig. 14.

with a pale tint of raw sienna. *In* the two square piles this wash may be perfectly flat, but in the round piles the tinting must be in accordance with the form.

It will be evident that when a cylindrical body is placed upright, the light will fall in a stream straight down the part which projects the most, and this part must, therefore, be preserved as bright as possible; in fact, there must be a perfectly white streak extending all the way down.

To effect this, you must use two brushes, the one rather larger than the other. Take some colour in the smaller one, and dip the other in water; touch the points of both on another piece of paper, so that they may not be overcharged, and by gently turning each round as you draw it along the waste paper you will bring the hairs to a point.

Now commence by drawing the brush containing the colour down the left side of the round pile, carefully avoiding passing over the line by which it is bounded. In this way colour a strip about one-eighth of an inch wide; do not leave a *pool* of colour, but merely tint the paper. Before this has time to

The rammer, which is made of beech or other hard wood, should be tinted of a lighter colour than that given to the guide-posts.

The pile is to be coloured and shaded as in the previous examples, but you will observe that there is on it the shadow cast by the rammer above; this is called the "cast-shadow," and must not have its lower edge smoothened off, as the sharp edge of the bottom of the rammer will cause the shadow cast on the cylindrical pile to be very well defined.

Fig. 24 is the front elevation of the same object, and will give further practice. The student is urged to observe the forms and tones of shadows cast by different objects; this he can easily manage—a cubical piece of wood or two, and a cylindrical piece, may be disposed in hundreds of ways, each affording a new study. This is the only way to gain real practice; for so long as the pupil only copies, he is merely repeating other men's works, and will only gain manual practice; *whilst by studying and making his own observations he will be laying up a store of information of which he will hourly find the value.*

Fig. 24.

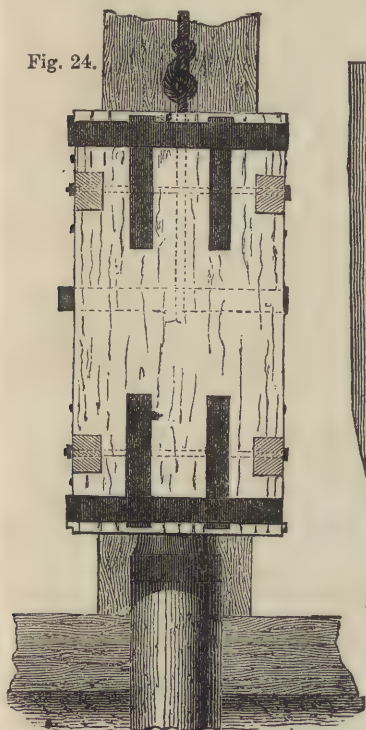


Fig. 21.

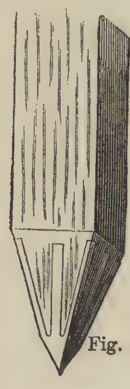


Fig. 19.

Fig. 20.

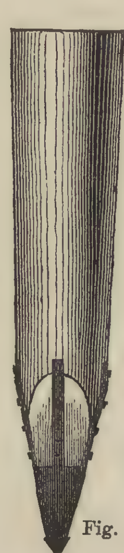
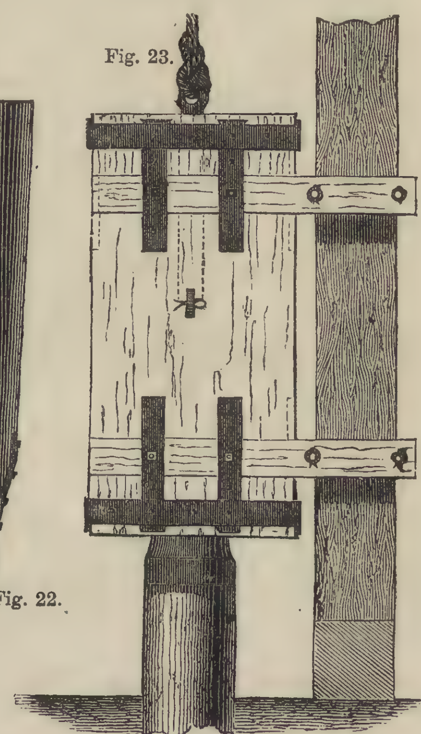


Fig. 22.

Fig. 23.



become dry, take your water-brush, and passing the point down the *inner* side of the part you have coloured, soften the edge away so that the colour may merge gradually into the bright white. Leave about the eighth of an inch quite dry, then pass your water-brush down, and next to this the colour, so as to produce the effect as on the other side; the colour becoming gradually fuller as it becomes further removed from the light.

Whilst the dark strip is still moist, wash off its edges, and merge it off into the local colour of the pile, and this should be done so gradually that as you ought not to be able to discover where the white light merges into the raw sienna, so you should not be able to discern the meeting of that colour with the sepia; but do not work your brushes up and down so as to produce a sleek or woolly effect. The shading and tinting should be bold and clear: a little practice will enable you to accomplish this. You are therefore advised to repeat such studies until you succeed. The iron shoe of the pile will, of course, be coloured with pale indigo.

Fig. 23 will afford another example for colouring and shading. The drawing represents the side elevation of the monkey (or rammer) and guide-posts of a simple pile-driving machine, with head of a round pile.

The shading is to be done in sepia; in the square piles this will simply consist in tinting the shaded sides with a flat tint. In the round piles, however, the shading must be managed in a similar manner to the colouring; dipping your middle-sized brush into the sepia, colour a strip the whole length of the pile. This darkest part, however, you will observe, is near, but *not* really on the outer edge of the cylindrical body. Further to the right side, you will notice the shade becomes lighter, and this is called the *reflected light.*

It may happen with beginners that the tints may not dry quite as smooth or as flat as they expected—irregularities, dark patches, or light spots, may appear. In the one case, a brush just moist should be worked over the dark part, by which means some of the superfluous colour may be removed. In some cases it may be necessary to rub the spot with a soft piece of india-rubber or bread. If neither of these processes is successful, a sponge should be drawn over the whole, and the work repeated when dry. In case of light spots appearing, they should be touched with the *point* of a brush containing colour; but care must be taken that *only* the light spot is touched. This is called *stippling*, and should only be used as a remedy. Tinting and shading should always be done in as free and bold a manner as possible.

VEGETABLE COMMERCIAL PRODUCTS.—II.

FARINACEOUS PLANTS (*continued*).

(*c.*) *The Leguminosæ* (*Pulse Family*).

THIS great natural family of plants contains numerous species with wholesome nutritious seeds, which, under the general term *pulse*, form important articles of commerce. These legumes comprise, in temperate climates, the Common Pea (*Pisum sativum*, L.), the Horse Bean (*Faba vulgaris*, Moench), the Haricot or French Bean (*Phaseolus vulgaris*, Sari), the Lentil (*Ervum lens*, L.); and, in the tropics, the Ground Nut (*Arachis hypogœa*, L.), the Chick Pea (*Cicer arietinum*, L.), and the Carob Bean, or St. John's Bread (*Ceratonia siliqua*, L.).

The legumes of temperate climates are familiar plants, and their mode of culture well known. Peas, beans, and lentils are grown in great quantities in Poland, Prussia, Pomerania, Denmark, East Friesland, and other countries. They create considerable business in the large sea-port towns on the Baltic and German seas, whole cargoes being brought to those places as provisions for ships. In 1866, 1,211,835 cwt. of peas were imported to this country, chiefly from Prussia and British North America; and the same year, 1,324,173 cwt. of beans were received, of which 615,912 cwt. were from Egypt, and the remainder from other countries. The tropical species of pulse are not so well known, and require description.

GROUND NUT (*Arachis hypogœa*, L.).—This plant is cultivated in America, in the Southern States, and forms an important article of food in many parts of Africa. It is a low, creeping plant, indigenous to the western coast of Africa, with yellow flowers, having the general appearance of a dwarf garden pea, although more bushy. After the flowers drop off, and the pods begin to form, the stalk or support of the pod elongates, *thrusting the pod under ground*, where it comes to maturity. The seeds contain a considerable quantity of oil. They are roasted in the pods, and are sold in the United States in large quantities, being a favourite dainty with children. This plant is very prolific, and in warm climates requires but little care and attention in its culture. In the green state it is greedily devoured by cattle.

CAROB BEAN, or ST. JOHN'S BREAD (*Ceratonia siliqua*, L.).—The carob tree is peculiarly Oriental, and abundant in Palestine. It has large pods, the seeds of which are enveloped in a sweet, nutritious pulp. It is supposed to be the locust bean on which St. John the Baptist fed when in the wilderness. This tree is common in the Levant and the south of Europe, where its beans are used as food. Most of the carob beans imported into this country come from Sicily and Naples. During the Peninsular war the horses of the British cavalry were frequently fed on these beans.

CHICK PEA (*Cicer arietinum*, L.).—This plant is a native of Southern Europe and the East. Its seeds are parched, and in Spain are sold in the shops for food. They are also abundant in the bazaars at Calcutta, and, under the name of *gram*, are sold as food for horses. Every part of this plant exudes oxalic acid, and it is used by the ryots of India in their curries instead of vinegar. When roasted, it is said to sustain life longer than other food in similarly small quantities; hence it is much used by travellers through the deserts, where the carriage of bulky food is inconvenient.

II. THE STARCHES OF COMMERCE, AND THE PLANTS WHICH PRODUCE THEM

Starch is an abundant product of the vegetable kingdom, and is in large demand for domestic and manufacturing purposes. It exists in all mealy farinaceous seeds, fruits, and roots, differing in its appearance according to the plants from which it is obtained. Starch is the nutritive matter of plants, and is changed by light to *chlorophyll*, and by oxygen to a sugary gum called *diastase*, which is carried into the circulation for the support of the new growths of plants. Starch is turned blue by iodine, an excellent test for detecting its presence in plants.

THE ARROWROOT PLANT (*Maranta arundinacea*, L.; natural order, *Marantaceæ*) is a native of tropical America and the West Indies. In arrowroot, tapioca, and sago, starch exists in a state of almost absolute purity. The arrowroot plant has large, herbaceous, very handsomely-striped leaves, and tuberous roots, which abound in fecula or starch. These roots are bruised, thrown into a vessel of water, and well stirred, when the fibrous portion comes to the surface, and is rejected, the starch settling at the bottom of the vessel as soon as the fluid is permitted to rest. This, after repeated washings, is dried in the sun, and constitutes the arrowroot of commerce, so much employed as a nutritive diet for invalids and young children.

Zamia integrifolia, Wild. (*Coontie*); natural order, *Cycadeæ*. —An arrowroot is now manufactured at Key West, in South Florida, from the stem of this plant, which is short and globular, and abounds in starch. This cycad, which was called by the Indians *coontie*, grows abundantly over an immense area of otherwise barren land. These manufactures bid fair to become as extensive and profitable as those of Bermuda, from whence at present our chief supplies of arrowroot are received.

Tous-le-mois, the starch of the rhizome of a species of canna (*C. coccinea?*); natural order, *Marantaceæ*.—This starch resembles a fine quality of arrowroot; but the granules are much larger than those, or of any known starch. Tous-les-mois comes from the island of St. Kitts, and is only used as food.

TAPIOCA PLANT (*Manihot utilissima*, Plum.; natural order, *Euphorbiaceæ*).—Tapioca is another form of starch, obtained by grating and washing the roots of this plant, which, under the name of manioc or cassava, forms a most important article of food in South America. This washing removes a narcotic poisonous principle which exists in the sap. The Indians dissipate it by heat, simply roasting the root. The starch thus washed, softened by heat, and afterwards granulated, constitutes tapioca. The ungranulated starch is the Brazilian arrowroot of commerce. The tapioca plant, in its native clime, is a shrub about five feet high, with roots which, when ripe, are about as large as a Swedish turnip, containing large quantities of this nutritive starch, and weighing sometimes thirty pounds.

The common starch of the shops, used in domestic economy, is obtained from wheat, rice, and potatoes, and is almost, if not entirely, home-manufactured.

SAGO PALMS (*Saguerus Rumphii*, Wild.; and *Sagus lævis*, Goertn.).—Sago is obtained from several species of palm. The sago of commerce is, however, chiefly produced by these two plants. It is obtained from the cellular tissue, or pith, in the interior of the trunk.

The sago palm produces, like rice, a chief means of nourishment for millions in warm climates, since sago powder is generally used for making bread. It grows in the south of China, Japan, and all over the East Indies, but principally in the islands of the Indian Archipelago. This palm generally grows in swampy ground, where it flourishes best, a good plantation, being often in a marsh, selected for that purpose. Its trunk is from five to six feet in circumference, rising to a height of about twenty feet. The pith, from which the sago is obtained, is of no use until the tree is fourteen or fifteen years old. A single tree is said to yield from five to six hundred pounds of sago.

Most of the sago imported into the United Kingdom comes to us in its granulated form from the island of Singapore, where it is manufactured as follows:—The pith, which is soft, white, spongy, and mealy, is first removed from the interior of the stem, then bruised, and put into large tubs of cold water; the woody particles of course float, and are easily removed, and the weightier starch or sago powder settles at the bottom of the vessel. The water is then poured off, and the dried sago powder passed through small sieves made of the fibres of the palm leaves. In passing through these sieves, the sago powder acquires its granulated character. The preparation is then finished, and the sago is ready to be put into boxes, or placed in bags, for shipment.

The exports from Singapore in the year 1847 exceeded 6,500,000 lb., but are now much larger.

Sago is insoluble in cold water, but by boiling becomes soft, and at last forms a gelatinous solution. In England it is much used for puddings; and as it is both nutritive and easy of digestion, it constitutes an excellent article of diet for the invalid and the convalescent.

A great deal of German or potato sago, from the manufactories of Vienna, Nuremberg, Schweinfurt, Erfurt, Halle, etc., comes into the European market, and it is with difficulty distinguishable from the real East Indian sago.

III. PLANTS YIELDING SPICES AND CONDIMENTS.

CINNAMON (*Cinnamomum Zeylanicum*, Nees.; natural order, *Lauraceæ*).—This plant is an evergreen aromatic tree, about

thirty feet in height, and indigenous to the island of Ceylon. Its leaves are oval, smooth, entire, with three prominent curvilinear ribs on the under surface. The young leaves are at first red, but change gradually to a yellowish-green, possessing the same flavour as the bark, but in a less degree; flowers panicled, white, with a brownish centre, devoid of fragrance, and about the same size as those of the lilac.

The inner bark of this tree constitutes the cinnamon of commerce, and the young twigs furnish the best. After the trees are nine years of age, the twigs are cut annually in the month of May, by the cinnamon peelers, or Choliahs, as they are called in Ceylon. This is done with a sharp iron instrument. The bark is removed by making a longitudinal and then a transverse incision into the shoot, inserting under the bark the point of the peeling-knife, and raising the handle of the knife as a lever. The next day the inner fibrous bark, in which resides the delightful flavour of cinnamon, is easily removed from the outer bark, and this, as it dries, curls up and forms quills. Before these quills become quite dry, hard, and brittle, the smaller are inserted into the larger; space in packing is thus saved, and compact sticks are formed, which are not so liable to breakage as the single quills. The wood from which the bark has been removed is sold for fuel.

"After hearing so much about the spicy gales from Ceylon," says Bishop Heber, "I was much disappointed at not being able to discover any scent, at least from the plants, in passing through the cinnamon gardens. There is a very fragrant-smelling flower growing under them, which at first led us into a belief that we smelt the cinnamon, but we were soon undeceived. On pulling off a leaf or a twig, one perceives the spicy odour very strongly; but I was surprised to hear that the flower has little or none."

Since neither the leaves nor the flower of the cinnamon-tree give forth any smell, it is only when the season arrives for gathering bark that the visitor to the gardens will enjoy the perfume of this plant. A walk through the cinnamon gardens during the busy season is truly charming. The grove is then full of fragrance, and a scene of cheerful industry. Everywhere are to be seen groups of Cingalese peeling the twigs, which they do with astonishing quickness, making a great deal of money whilst the season lasts. The Choliahs form a distinct caste, and are considered very low, socially, so that, according to Cingalese notions, it is personally degrading for any one else to follow the business. The largest of the cinnamon gardens in Ceylon is that near Colombo, which covers upwards of 17,000 acres of land.

Cinnamon-trees are preserved with the greatest care by their proprietors. By the old Dutch law the penalty for cutting or injuring them was amputation of the hand; at present a fine is imposed upon the delinquent.

In 1866 932,729 lb., and in 1867 859,034 lb. of cinnamon were imported into this country, a great part of which we re-exported to our colonies. Considering the extreme lightness of cinnamon bark, this is a large quantity. Cinnamon is usually brought home in bags or bales of from eighty to ninety pounds' weight. The best comes from Ceylon, but the cinnamon-tree grows plentifully in Java, Sumatra, Malabar, and Cochin-China, and it has been recently transplanted to the Mauritius, the Brazils, and Guiana, and to the West India islands of Tobago, Guadaloupe, Martinique, and Jamaica. The cinnamon produced in the West is, however, not so good as the Oriental.

Cinnamon is an aromatic tonic of an agreeable odour and taste, which acts as a grateful stimulant or carminative, creating warmth of stomach, removing nausea, expelling flatulency, and relieving colic or intestinal pain. It owes these properties to the volatile oil which it contains. Cinnamon is much employed as a condiment in culinary preparations, and is also frequently used for flavouring and disguising unpleasant medicines, or as an adjuvant—that is to say, an assistant.

Cinnamomum Cassia seems to be the chief source of the *Cassia lignea*, or bastard cinnamon of commerce. This plant differs from the true cinnamon-tree in many particulars. Its leaves are oblong-lanceolate, and have the taste of cinnamon, to which also its bark bears a great resemblance, but is thicker, rougher, denser, and not so agreeable in flavour. It is cultivated in China, and is imported from Canton, *viâ* Singapore, in chests similar to those in which the tea is packed. 349,349 lb. of *Cassia lignea* were imported in 1866.

NUTMEG-TREE (*Myristica moschata*, Thunberg).—This tree, from twenty to twenty-five feet in height, strongly resembles our pear-tree in its general appearance, and also in its fruit, which is not unlike the round Burgundy pear. The leaves are alternate, smooth, entire, oblong-pointed, short-petioled, and aromatic when bruised; the flowers axillary, racemose, pale, bell-shaped, without a calyx. The fruit is a fleshy pericarp, opening by two valves when ripe, and displaying the beautiful scarlet reticulated arillus, or mace, enveloping the thin, dark-brown, glossy, oval shell, which covers the kernel, the nutmeg of the shops. Each fruit contains a single seed, or nutmeg. The mace and the nutmeg are both valuable spices. The former, although a brilliant scarlet colour when fresh, becomes yellow, brown, and brittle when dry.

Whilst the clove has spread over Asia, Africa, and the West Indies, the nutmeg-tree refuses to flourish, except in the islands of the Malayan Archipelago, where it appears to be indigenous. In 1819, 100,000 of these trees were transplanted by the British Government to Ceylon and Bengal, but the plantations were not successful. All attempts to introduce the nutmeg-tree into other tropical countries have failed.

The Dutch endeavoured to extirpate the nutmeg from all the islands of the Moluccas except Banda, and they had all the trees removed thither for better inspection; but this attempted monopoly was completely frustrated by the mace-feeding wood-pigeons. These birds conveyed and dropped the fruit beyond the assigned limits, spreading it over the whole of the islands of the Malayan Archipelago, from the Moluccas and New Guinea.

About 251 tons of nutmegs, and 68 tons of mace, were imported into the United Kingdom in 1866, nearly half of which were re-exported.

The nutmeg and clove trees were first introduced into this country by Sir Joseph Banks, as ornamental hot-house plants, about 1797.

Nutmegs and mace are employed chiefly as condiments for culinary purposes, for which they are admirably suited by their agreeable taste and stimulating properties. As remedial agents they owe their activity to the volatile oil which they contain, and when administered in moderate quantities, produce the usual effect of the other spices.

THE CLOVE-TREE (*Caryophyllus aromaticus*, Linn.; natural order, *Myrtaceæ*, the Myrtle family).—Cloves are the unexpanded flower-buds of this tree, which is an evergreen, the trunk rising from fifteen to twenty feet above the ground. The leaves are opposite, rigid, ovate-lanceolate, smooth, entire, petioled. The flowers are produced in great profusion, in short terminal panicles of from nine to eighteen in each bunch. The four leaves or sepals of the calyx are united; the base of the calyx is tapering and somewhat quadrangular. The corolla is red, and before expansion, forms a ball or sphere at the top of the calyx. The peduncles, or flower-stalks, are divided into threes, and articulated or jointed. This greatly facilitates the fall of the buds when the gatherers beat the trees with reeds or wands. They are also gathered by hand—a method adopted when the season has been unfavourable.

The clove-tree is a native of the Moluccas, where it was very abundant before the conquest of these islands by the Dutch. They extirpated it from all the Moluccas except Amboyna, and even there they allowed only a limited number of trees to be planted, lest the *price should fall too low!* This narrow policy stimulated other nations to try to get so valuable a spice. In 1770 the French obtained the plant, and introduced it into the Isle of Bourbon, and from thence to Cayenne and to their other possessions in America. But the best cloves still come from the Moluccas.

We receive cloves from the East and West Indies, from the Mauritius, and indirectly from Holland. The quantity imported in 1866 was 541 tons.

Dr. Ruschenberger, who visited Zanzibar, on the eastern coast of Africa, in 1835, thus speaks of the clove plantations there:—"As far as the eye could reach over a beautifully undulating land, nothing was to be seen but clove-trees of different ages, varying in height from five to twenty feet. The form of the tree is conical; the branches grow at nearly right angles with the trunk, and they begin to shoot a few inches from the ground. The plantation contains nearly 4,000 trees, and each tree yields, on an average, six pounds of cloves

annually. They are carefully picked by hand, and then dried in the shade. We saw numbers of slaves standing on ladders gathering the spice, while others were at work clearing the ground of dead leaves. The whole is in the finest order, presenting a picture of industry and of admirable neatness and beauty."

Cloves, when good, are dark, heavy, and strongly fragrant, the ball on the top being unbroken, and yielding oil when pressed with the nail. This oil is sometimes extracted, and the cloves so treated are mixed with the others. They are also sometimes adulterated with water, which they absorb readily, becoming plumper and heavier.

Cloves are much employed in cookery as a condiment, being the most stimulating of the spices. The oil of cloves is a popular remedy for the toothache, and the infusion a warm and grateful stomachic. Cloves are frequently employed by medical men to disguise the nauseous properties of their drugs, and thus render them more palatable to the patient.

THE ELECTRIC TELEGRAPH.—I.

By J. M. Wigner, B.A.

THE BATTERIES EMPLOYED—INSULATORS—LINE WIRES.

One of the features by which the present century has been rendered especially remarkable is the number and importance of its scientific inventions. Among these there is none more wonderful than the electric telegraph, and none which has more rapidly passed from being a mere scientific toy, valuable only for the elucidation of certain principles and facts, into becoming a great and important instrument in the conduct of our everyday business. Scarcely half a century has elapsed since Professor Oersted made the discovery that a magnetised needle was deflected by the passage of an electric current along a wire placed near to it, and the mode of converting a bar of iron into a temporary magnet by means of the electric current was not discovered till several years subsequently, and yet, at the present time, the messages weekly transmitted, in this country alone, by instruments based on these principles are numbered by the hundred thousand; and there is scarcely any part of the globe that is not traversed by wires, along which our thoughts are constantly being flashed with a speed almost equal to their own.

In the articles on "Voltaic Electricity," which have already appeared in The Popular Educator, a general account has been given of the principle on which the various forms of telegraph instruments act. In the present series we propose to give a practical explanation of the construction of the different instruments and the manner of using them, so as to enable the intelligent amateur to construct such instruments for himself, and to help the telegraphist to understand the mechanism of the apparatus he is employing.

To transmit messages by electricity, it is, of course, necessary in the first place to have some means of generating an electric current of sufficient quantity and intensity. We must further have some way of conveying this to the desired place, and also of causing it to produce at that place such effects as shall enable us to make our messages understood.

For generating an electric current, any one of the many forms of battery already described may be employed. The Cruickshank battery, consisting of alternate plates of copper and zinc excited by a solution of dilute sulphuric acid, was for a long time that generally adopted. Very frequently the cells were filled in with fine sand, over which the solution was poured. This form was commonly known as the Sand battery. Smee's and other forms have also occasionally been tried, but in almost all cases these batteries have now been superseded, and some modification of Daniell's sulphate of copper battery adopted. In the large cellars under the Central Telegraph Offices in Lothbury, there are thousands of cells of these batteries constantly at work. The standard form now adopted consists of a trough about two or two and a-half feet long. This is made of hard wood, and carefully coated inside with a resinous composition so as to prevent the acid from eating it away. Water-tight compartments are then fixed at about equal distances, so as to divide the trough into ten cells, and each of these is subdivided by a plate of porous or unglazed earthenware, represented in Fig. 1 by the thinner lines.

Plates of sheet copper are then cut about four or five inches square, and zinc is cast into thicker cakes of a similar size. A piece of copper and one of zinc are then connected together by a copper band riveted to each, as shown in Fig. 2. The band or strap is then bent in the middle, so that the copper plate may be in one cell and the zinc in the next. A lid is provided to each trough; this serves to exclude the dust, and at the same time, by checking evaporation, renders the action of the battery much more uniform.

The cells which contain the zincs are charged with dilute sulphuric acid, or with a solution of sulphate of zinc; those in

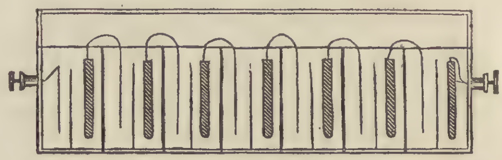


Fig. 1.

which the copper plates are placed contain a saturated solution of sulphate of copper (blue-stone), and, as the copper is precipitated on the plate by the action of the battery, the cells are usually filled up with crystals, so as to maintain the strength of the solution. If it gets exhausted, a portion of the zinc solution passes through the porous partition, and this metal is thrown down on the copper, rendering it almost black. For each equivalent (26 parts) of zinc dissolved in any cell, an equivalent ($25\frac{1}{2}$ parts) of copper is precipitated in the corresponding cell, and hence the copper plate increases in thickness while the zinc is eaten away.

When the acid becomes saturated with zinc the action of the battery is much diminished; a portion of the solution should therefore be removed, and the cell filled up with water.

Care must be taken not to let the zinc plate rest in contact with the diaphragm, as in that case metallic copper is deposited on it, and it is soon broken. After having been used the partition should also be kept moist, as, if allowed to dry, the sulphate of zinc effloresces round the edges and chips away small pieces.

The porous diaphragm does not entirely prevent the two solutions mixing, though it checks it very considerably. Some of the copper passes into the zinc cell, and, being there decomposed by the action of the zinc, falls to the bottom as a dark powder usually known as the "mud" of Daniell's battery. When an inner porous cell is used instead of a partition, it is usually greased all over, except on the portion opposite to the copper plate, so as to check as far as possible this mixture.

In some instances the porous diaphragm is entirely dispensed with, and the two solutions are kept separate by their respective weights alone. The copper solution, having the greater density, is first poured into the cell so as to half fill it; the acid is then carefully put in above it. In this form of battery the copper plate is placed at the lower part of the cell, and the zinc plate at the upper portion, so that the two do not overlap. The copper solution, however, in time mixes with the acid, and this battery is not very much employed.

Fig. 2.

In working batteries it is found that the same amount of zinc is consumed in each cell; it is advisable, therefore, only to employ plates of similar size in the same circuit. A single weak or defective cell will retard the passage of the entire current, and thus cause a very considerable waste of power.

It should be remembered that the *quantity* of electricity generated is not augmented by increasing the number of the cells; it is only the *intensity* that is thus affected. To increase the quantity we must increase the size of our cells, or, which practically amounts to the same thing, arrange two or three side by side, their zinc and copper plates being respectively connected. As a general rule, for distances of a few miles, a single trough containing ten or twelve cells is amply sufficient, provided it be working well. If it is losing its power, or the message has to be sent to a much greater distance, two or more of the troughs may be joined together.

Having now seen the manner in which the electric current is generated, we have next to ascertain the mode in which it can be conveyed to any required place. As we have already

learnt, the fluid very easily escapes, unless the conductor along which it is travelling is carefully insulated. When the wires are laid under the surface of the ground or at the bottom of the sea, this is accomplished by coating them with some insulating material in a way that will shortly be explained. In most cases, however, the lines are suspended in the air, which is, for all practical purposes, a non-conductor. All need for coating the wire is then at an end, and it is only necessary to make some arrangements which shall prevent the escape of the electricity at the points of support. This is accomplished by means of "insulators," a few of the forms of which were figured in the papers on "Voltaic Electricity."

In large towns the insulators are very frequently attached to the corners of lofty buildings, or to stacks of chimneys, and in this way much expense is avoided, and the wires are at the same time so much elevated that they do not interfere with the ordinary traffic of the streets. In the open country, however, they are supported on posts specially erected for the purpose, which under ordinary circumstances are placed at distances of about sixty yards apart, and the wires are about eighteen or twenty feet above the surface of the ground. Young fir or larch trees are usually chosen for the purpose, and roughly trimmed. Sometimes the wood is impregnated with a preservative compound to guard against decay. When this is not done, the pole is charred along the lower end for a length of several feet. The charred ends are sometimes allowed to stand in gas-tar for several hours as a further protection; but still, with every precaution, it is found that the post will decay at the ground-line, where it is exposed to the air as well as to the moisture of the earth.

In different parts of the Continent and in India, where wooden posts are far less durable, substitutes have been tried, and iron tubes and posts of different forms have been used to a considerable extent. The first cost of these is, of course, considerably greater, but in the long run a great saving is effected by their employment, and it seems probable that in England they may eventually become much more generally adopted. When the line is straight the strain is but small, but at an angle it is considerably increased, and struts or stays are usually employed to strengthen the posts.

In some places the plan has been tried of affixing the insulators to the stems of living trees, and this has been found to answer very well. The swaying of trees during storms is a slight objection, but a swinging insulator designed by a Prussian officer, Lieut.-Colonel Chauvin, meets this difficulty. The construction of this will easily be understood by reference to Fig. 3. The bent iron rod, A B, is cut at one end into a screw, and fixed firmly into the tree, while the other end is flattened out, and fastened by means of a screw. The insulator, C, is suspended from the ring D by the hook F, the end of which is turned back so as to prevent the wire jerking out when the tree is shaken. In the lower part of the insulator is fixed another hook through which the line wire passes. This is, of course, quite insulated from F, and is so bent that when the insulator swings to and fro with the wind, only the porcelain comes in contact with the tree or the support.

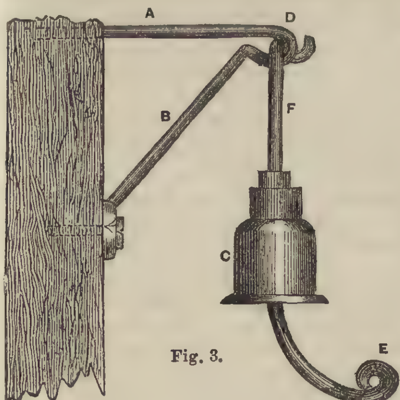


Fig. 3.

Almost every telegraph engineer has his preference for some special form of insulator, and hence there is a great variety. That most generally employed in this country is represented in Fig. 4. It consists of two inverted cups of brown earthenware, fitting inside one another. To the inner one is fixed the steel stalk by means of which the insulator is firmly bolted to the post, while round the outer is a groove to which the line wire is fastened. The two are fixed together by means of a non-conducting cement. On about one post in every ten a stretching-insulator is placed. The wire is found to give a little by the continued strain, and also to vary in tension with changes in the temperature. The result of this, if unchecked, would be to cause the wires to hang so loosely that when, as is generally the case, there were several on one post, they would strike against one another, and thus greatly interfere with the communication. These insulators are accordingly provided, and by means of them the wires are kept duly strained.

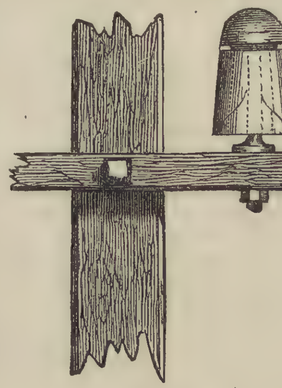


Fig. 4.

Frequently, especially in lines supported on buildings, the wire is fixed to every insulator, instead of merely resting in a loop, and then there is less need of stretching-insulators. The importance of careful insulation is very great, especially in long lines, as a very trifling loss at each point of support will soon seriously weaken the current, and render much more battery power necessary to transmit the message.

Copper wire is the best conductor by far, and might therefore be used of much smaller size than the iron wire usually employed. This would probably cause a considerable ultimate saving, as the posts and insulators need not be so strong; but the value of the wire would render it so strong a temptation, that the lines would not unfrequently be cut. From this and other causes iron wire is always employed. For general purposes that known as No. 8 gauge is used, its diameter being 0·170 inch, and its breaking weight about 16 cwt. Unless, however, the wire be protected in some way it soon rusts, and becomes corroded by the influence of the air and moisture. Sometimes it is coated with tar or boiled linseed oil. More frequently, however, in this country, the wire is "galvanised," or coated with metallic zinc, and this serves as a very good protection, except in the neighbourhood of manufacturing towns, where the smoke from the various factories soon corrodes away the zinc. In some cases, instead of a single wire, a strand composed of seven wires of No. 20 gauge is used, and this is by many considered preferable.

COLOUR.—I.

By Professor Church, Royal Agricultural College, Cirencester.

INTRODUCTION — CONNECTION OF THE SCIENCE OF OPTICS WITH COLOUR.

Owing to the dependence of colour upon light we must begin our study of its laws and their applications by a statement of two or three of the chief facts of Optics. We wish now to direct our readers' attention to the reflection, the emission, the transmission, the absorption, the refraction, and the dispersion of light.

Everything that we can see is visible owing to its reflection of light, or to its emission of it: the former action produces or characterises illuminated bodies; the latter, luminous bodies. Illuminated bodies are marked out and distinguished from one another by the different amounts and qualities of the light which they reflect. A piece of black cloth on a white porcelain plate reflects but a very small part of the light which falls upon it; the plate, on the other hand, reflects much. Had the black cloth possessed no power of reflecting light, it would have been invisible; black velvet, which reflects less light, sometimes produces to the eye the effect of absolute blackness, that is, of an empty and dark space. Similarly, a sheet of plate glass may appear lustrous and visible enough if the light which falls on it is sent back to the eye; but if we are so placed in front of the glass that these rays escape us, it ceases to be visible, and we may, perchance, stretch out our hand to take something from behind the glass, wholly unconscious of its existence. But it is possible to render a piece of polished glass

permanently visible. Crush it to powder, and then in whatever direction the light falls upon its particles the surfaces of those particles will turn back or reflect some of the rays, and so render themselves visible. The clear glass has become opaque.

For the very same reason dense clouds, which appear black when between the observer's eye and the sky, owing to the complete way in which they cut off the light, may become brilliantly white when the sun's rays fall upon their constituent particles, owing to the very same action; for the light, which cannot get through the cloud, is continually reflected to and fro from the surfaces of its minute parts, and thus illuminates it. Thus it happens that the lower half of a cloud against a dark mountain may appear white, while the upper part of the same cloud against a luminous sky may appear a dull grey. The lessening of reflection, on the other hand, diminishes visibility. The numerous small reflections which occur between the surfaces of the fibres in a piece of paper may be greatly reduced by wetting or oiling the paper, when it becomes less opaque and at the same time greyer and clearer: to this cause the transparency of tracing paper and tracing cloth is due.

We said above that bodies differ not only in the amount but in the quality of the light which they reflect. Now one of the chief differences as to quality of light is the difference of colour. Powdered vermilion reflects much light to the eye; this light, however, is chiefly red light, though there is some white light mixed with it. A stick of red sealing-wax shows in some positions a bar of white reflected light in the direction of its length, while in other positions we see only the red light reflected from the particles at its surface and a small depth below. Why this light happens to be red in the vermilion we shall discuss further on: we would only point out here that while the reflection from a polished surface is regular, that from a rough surface is irregular, and that from a coloured surface coloured. A polished plane metallic surface affords an example of the first kind of reflection, a piece of chalk of the second. So great is the difference in effect produced by regular reflection from that produced by irregular reflection, that if an illuminated polished body could be found which was wholly incapable of irregularly reflecting any part of the light falling upon it, that body would be invisible. We may, therefore, say that we discern bodies by the aid of the light which they reflect irregularly, or scatter; a perfectly regular reflection gives, on the contrary, an image of the source of light, not of the object illuminated. It is only light which is regularly reflected which can be shown to obey the great law of reflection, which is this:—The angle which an incident ray of light makes with a perpendicular to the reflecting surface, is equal to the angle which the reflected ray makes with that perpendicular; in other words, the angle of incidence and the angle of reflection are equal. Another law here to be mentioned is, that both the incident and the reflected rays of light are in the same plane, which is perpendicular to the reflecting surface. We shall have to refer to these laws of reflection, to reflection at varying angles and from different substances, and to the different kinds of reflection enumerated above, when we proceed to discuss the subject of Colour.

A few words may now be said on luminous bodies, or those which emit light. A candle flame, a glowing piece of charcoal, and the sun, are examples of luminous bodies. From these sources of light luminous rays are sent out; these rays are the lines in which the light is propagated; luminous pencils are bundles of such rays. From such luminous bodies as are near the eye the rays emitted are divergent, but the rays from the sun and distant bright bodies are practically parallel. Highly luminous bodies can only be clearly seen when much of the light which they emit is cut off by a special contrivance, such as a piece of smoked or dark-green glass. It is thus quite possible to see the form and changes of the coke-points of the electric lamp, intense as its light is.

The light emitted from bodies travels in straight lines, and causes the production of shadows. The form and sharpness of shadows is influenced not only by the shape and the relative size of the opaque body which casts the shadow, but by the form of the luminous body, the light of which is intercepted. A luminous point gives a sharply-defined shadow, while a luminous surface, on the other hand, gives a dark shadow surrounded by a paler and less definite one which goes by the name of a penumbra.

We have so far spoken of the reflection and of the emission of light: the transmission of light has now to be considered. Bodies are said to be *transparent* when they permit light freely to pass, so as to allow objects to be distinguished through them; *translucent*, when they allow light to pass less perfectly, and objects on the other side of them cannot be clearly discerned; *opaque*, when light is wholly cut off. But in reality no bodies are perfectly transparent or perfectly opaque. The most colourless and flawless polished glass cuts off some rays, while substances, such as metals, which are commonly considered quite opaque, become transparent when reduced to the form of thin leaves. The sun may be conveniently viewed through a glass thinly coated with silver, while the light transmitted by an ordinary piece of gold-leaf is grass-green.

In addition to this, it may be remarked that different transparent bodies permit the light to pass through them with more or less facility, but they also variously affect the light which finds its way into them. Suppose the case of water. A beam of light made up, we will suppose, of 1,000 rays, strikes the water perpendicularly; 18 rays will then be reflected towards the luminous source, while 982 will find their way through the water unchanged, unless the layer of water be of considerable thickness. Now introduce into the water a drop of some red solution; the light transmitted will be filtered light, the red solution having strained off some of the constituent rays and left the others. The intensity of the light and its quality will thus have been altered by transmission, just as they are by reflection. Colour, in fact, may be produced from white light, either by the absorption of some parts of the luminous rays and the reflection of others, or by the absorption of some parts and the transmission of others; but, as we shall point out presently, there are several other ways of producing colour without the intervention of an absorbent body.

Before, however, we can profitably study these ways, and the curious phenomenon of absorption itself, we must become acquainted with the main features of the theory of light. This theory is called the *undulatory* theory.

The undulatory theory supposes the existence, throughout all space and throughout all matter, of an infinitely thin, elastic medium called the luminiferous or light-bearing ether. It must be supposed that this ether is not only universally present, but present without break in its continuity. It exists in space, in all solids, liquids, and gases, and it cannot be excluded from what we call a vacuum. It can hardly be material in the sense in which the sixty-three elements of the chemist are material; but to account for the properties of light, we must presume the medium which conveys it to have some at least of the properties of matter. The movement of this ether is light. It undulates in waves, the undulations of the particles of the ether being across the direction in which the light is propagated. Light is supposed to originate in the following manner:—The particles or molecules which constitute a luminous body are in a state of disturbance, a state of intensely rapid motion. This motion of the molecules is communicated to the ether and sets it in vibration, and is propagated in all directions in the form of spherical waves. Reaching the retina, this fine motion of the ether excites vision and becomes sensible as light. With these statements of the main assumptions of the wave-theory of light before us, we shall be able to consider with exactness not only the absorption and refraction of light, but the several modes of the production of colour.

The waves of the ether are of different lengths; in pure white light, such as that emitted by the electric arc, waves of all lengths occur between the limits of about $\frac{1}{30000}$ of an inch on the one hand, and about $\frac{1}{60000}$ of an inch on the other hand. Now the colour of light is solely dependent upon the length of the wave. The longest wave that is perceived by the retina is the red wave, the shortest the violet. Longer waves than the red waves possess a high heating power; shorter waves than the violet, invisible to the eye, and with scarcely any action on the thermometer, are gifted with a great degree of chemical energy: they are called actinic. If we use the electric light, which is really a more perfect light than that of the sun, we shall find that it emits or causes undulations, the waves of which are of much wider differences as to length than those of the red and violet lights above mentioned. By means of various solutions we can absorb some of the rays: those of light can, for instance, be strained off, and those of heat and actinism trans-

mitted. The waves of certain lengths cannot undulate in a solution of iodine in carbon disulphide, they are arrested or quenched thereby. Such a solution, indeed, permits only the rays of dark heat to pass through it; but the undulations of this dark heat may be changed, and their wave-lengths may be diminished by allowing the invisible heat-rays to be concentrated in a focus and to fall upon a solid, infusible body. This solid will become hot and then luminous—heat has been changed into light. This passage of calorific into luminous rays is known as *calorescence*, and may be made so complete a change that all the colours of the rainbow may be thus obtained from a perfectly dark source of heat. But exactly the same sort of change may be effected with the invisible actinic rays, the wave-lengths of which are shorter even than those of light. By using a solution of blue vitriol in ammonia, dark rays of chemical energy may be transmitted and freed from the visible rays. Receive these dark rays upon a screen of fluor spar, or Canary glass, or solution of quinine sulphate, light and colour are produced. The wave-lengths of the actinic undulations have been increased; the invisible chemical rays have passed into visible luminous rays; this passage is called *fluorescence*. Another name for the change in wave-length which we have just described is *change in refrangibility*.

We will now proceed to describe the meaning of the expressions *refraction* and *refrangibility*.

When a beam of light falls perpendicularly upon water, more than 98 per cent. of the rays pursue a straight course through the water. Let the incidence of the beam be oblique, and then it will be found that fewer rays will penetrate the surface, and that those which do will not pass through the water in a straight line, but will be more or less bent out of that line: this bending is called *refraction*. Refraction takes place when a beam of light passes obliquely from a rarer to a denser medium, or *vice versâ*. Instances of refraction have been already alluded to and described in THE POPULAR EDUCATOR (see "Recreative Science," Vol. V., p. 223) in the case of a stick half immersed in water, which appears broken owing to refraction; and of a coin, which, lying invisible at the bottom of a basin, may be made to appear by pouring water upon it, and so bending back the rays, which are reflected by the coin, till they reach the eye. In passing from air into water or glass the refracted ray is bent towards the perpendicular; in passing out of water or glass into air the reverse refraction occurs, and to a precisely equivalent extent. If, therefore, a beam of light enters obliquely a piece of glass, the faces of which are parallel, the refraction towards the perpendicular on entering the glass will be exactly compensated by the refraction from the perpendicular on leaving the lower surface, and so the emergent ray will necessarily be parallel with the incident ray. But supposing we employ a prism of glass instead of a flat plate, then the ray is permanently refracted. The prism so much employed in Optics is a wedge-shaped piece of flint glass, and is an indispensable instrument in the study of colour. The angle enclosed by two oblique sides of this prism is called the refracting angle. If we place the prism so that this angle shall be below, and the opposite side of the prism horizontal, then a beam of light falling from above on to one of the oblique sides will be refracted towards the refracting angle, and passing across to the other oblique side will pass out, with its path changed again, but now in an upward direction. But something more will have commonly happened to the beam besides its permanent refraction. If the light be simple, if its wave-lengths be of one measure only, it will be simply deflected; but if, as is nearly always the case, the light be compound—if its waves are of different lengths—then the prism will differently affect them. It will retard the short waves more than the long ones, and so we shall find that these short waves are more refracted. The more refrangible rays are then the short violet rays, the less refrangible rays are the longer red rays. In every case, therefore, where a luminous body emits rays of various refrangibilities, these rays can be separated from each other by means of the prism. As solar light consists of an enormous number of rays of different refrangibilities, it may be decomposed, analysed, or split into an enormous number of coloured lights, the wave-length of each of which belongs to a particular ray. The electric light gives an infinite number of such coloured lights, for there are no breaks in its series of rays, such as exist in the light of the sun. Burning metals and glowing gases emit, on the other hand, fewer rays, and give fewer colours, when their light is prismatically decomposed. The decomposition, or splitting up of light by the prism, is called the *dispersion* of light; the coloured image formed is called a *spectrum*. We are enabled to study the origin, the properties, and the changes of colours by means of this spectrum.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—I.

IT is intended in the present course of lessons to show the practical application of Geometry to trade and manufactures, in order to give to students engaged in the several constructive arts, and the various branches of industry involving skilled labour, a thorough and practical knowledge of the methods of describing the various figures required, by the most ready and correct processes.

It is impossible to over-estimate the importance of a knowledge of Geometry, forming as it does the basis of all mechanical and decorative arts, constituting, in fact, the grand highway from which the various branches of Drawing diverge.

Nor must the study of Practical Geometry be estimated by its mechanical value only, for its uses extend far beyond the necessities of trade and manufactures. It gives to the eye that absolute correctness of perception, that clear idea of form and size, which, as branches of education, render it most important to all; and, further, it will be found that it gives to the mind that habit of accurate arrangement, that order in mental processes, which must act beneficially on all persons, whatever may be their position.

In the present course, it is not proposed to give more of the definitions or elementary figures than may be absolutely necessary, the object being to apply *knowledge* to *practice*. Still the lessons will, as far as possible, be made self-explanatory, and the methods of drawing figures will be thoroughly explained.

The subject, then, is not to be treated as a mathematical, but as a thoroughly practical one, and therefore no absolute system of reasoning is attempted. Still, it has been thought right to give some simple and familiar explanations of the properties of the various figures, and the principles upon which their constructions are based, as it must be obvious that the more the mind comprehends of the relation of one line and form to another, the more will the eye appreciate beauty and refinement, and the more accurately and intelligently will the hand execute.

In order to guide students in using these lessons for self-instruction, the processes in each figure are lettered in the order of the alphabet; the consecutive steps by which the result is attained will thus become evident. This plan is assisted by the imaginary or constructive portions being drawn in dots, or fine lines, the given figures in medium, and the resultant forms in full black lines.

The lessons are intended, therefore, as stepping-stones to Technical Drawing in all its branches, and it is hoped that by their means the artisan may be enabled to construct the forms required in his trade by rapid and certain means, instead of blindly following the traditional methods existing amongst the men in "the shop;" and it is hoped that when he has thus become acquainted with the "grammar of form," he may be able himself to originate and invent, and so be able to keep pace with the progress made, not only in foreign countries but in our own.

We commence, then, with certain figures constantly used in mechanical drawing, repeating such of the early studies as may be required in any particular figure, thus avoiding reference to back numbers as much as possible. The student is, however, supposed to have mastered such problems as bisecting lines, etc., and if he has not done so he will find them thoroughly explained in the "Lessons in Geometry" in THE POPULAR EDUCATOR.

One of the most frequently occurring processes is that of dividing lines into a certain number of equal parts. The want of knowledge of rapid methods causes waste of time, and by constant trials the paper becomes frayed and roughened, to the great detriment of the drawing. The following figure and its application is therefore given:—

To divide the line A B *into any number of equal parts* (in this case ten). (Fig. 1.)

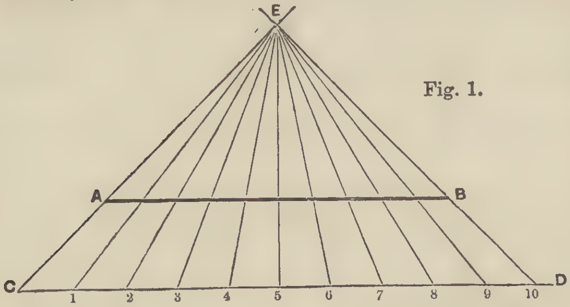


Fig. 1.

Draw a line (C D) parallel to A B. (The line C D may be any length, that is, it may be drawn indefinitely for the present.)

From C set off along this line the number of parts into which the line A B is to be divided—viz., 1 to 10. These parts may be *any* convenient size, but must be all equal.

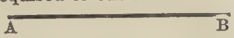
Draw C A and 10 B, and produce* both lines until they meet in E.

From each of the points 1, 2, 3, etc., draw lines to the point E, which passing through A B will divide it into 10 equal parts.

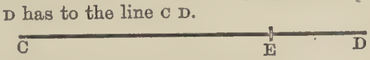
Application No. 1 *of the foregoing figure* (Fig. 2).

This problem may also be used for dividing a line proportionally to another, that is, to find divisions on a line, which shall be in the same proportion to it, that certain divisions are to another line either larger or smaller.

Thus, let it be required to cut off from



a part which shall have the same proportion to it that the division E D has to the line C D.



Place A B parallel to C D, as in Fig. 2.

Join C A and D B, and produce the lines until they meet in F.

From E draw E F, which passing through A B will cut off G B, which will have the same proportion to A B that E D has to C D.

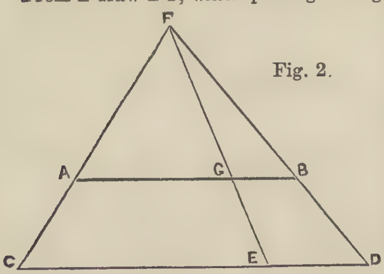


Fig. 2.

This process is constantly used in finding the proportions of architectural mouldings, windows, mechanical details, etc., in making reduced or enlarged drawings.

This problem is also most useful in finding a particular point in a line which may be so small as to render accurate division very difficult.

Example: The length from A to B in a spur† wheel (Fig. 3),

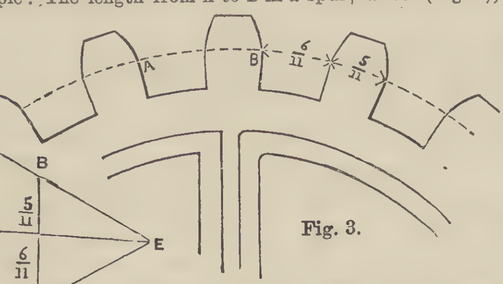


Fig. 3.

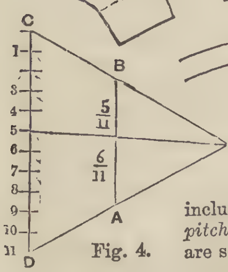


Fig. 4.

including a *tooth* and a *space*, is called the *pitch*, and the circle on which such distances are set off is called the *pitch circle.*

Now although in many drawings the space and tooth are made equal, they are not so in a real spur wheel, the space being a very little larger than the tooth. This small difference is most important, for if the tooth and space were equal, the tooth of a wheel when in gear with another would not clear itself. The difference of one-eleventh is found in practice to be sufficient for all purposes. Thus, if the "pitch" is divided into eleven equal parts, the tooth will be five-elevenths, and the space six-elevenths.

But dividing the space A B (which in many cases is much smaller than as given above) will be found liable to some inaccuracy: by this problem, however, the required point of division may be found with ease and exactness.

Let A B (Fig. 4) be the length of the pitch, measured from A B in Fig. 3. Draw any line, C D, parallel to A B, and set off on it 11 equal divisions (*any* length).

Draw C B and D A, and produce the lines to meet in E.

From point 5 draw a line to E, which will divide A B as required, the one part being $\frac{5}{11}$ and the other $\frac{6}{11}$.

Set off these lengths on the pitch circle.*

To construct an equilateral triangle on the given line A B (Fig. 5).

From A, with radius A B, describe an arc.

From B, with the same radius, describe a corresponding arc, cutting the former one in C.

Lines joining A C and B C will complete the triangle, which will be equilateral, that is, all its sides will be equal.

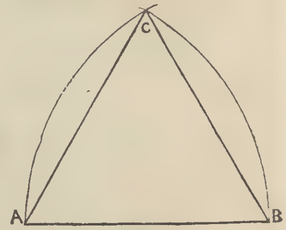
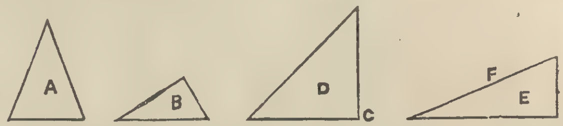


Fig. 5.

A triangle having only two of its sides equal, is called an *isosceles triangle* (A).

When all three sides are of unequal length, the figure is called a *scalene triangle*, as B.



In a right-angled triangle, one of the angles, as C, is a right angle.

A right-angled triangle may be either isosceles, as D, or scalene, as E.

The longest side of a right-angled triangle, viz., the side opposite to the right angle, viz., F, is called the *hypothenuse.*

When a line, C D (Fig. 6), stands perpendicularly on another line, A B, it divides the space into two right angles; if produced

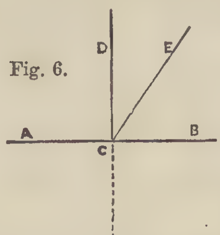


Fig. 6.

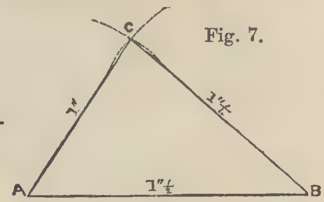


Fig. 7.

beyond C, four right angles will be formed; but if the line C E be drawn, dividing the space unequally, the angle A C E is an obtuse (or wide) angle, being *more* than a right angle, and the remaining portion, B C E, is an acute (or sharp) angle, being less than a right angle.

To construct a triangle of given dimensions (Fig. 7).

Let it be required that the sides of the triangle should be $1\frac{1}{2}''$, $1''$, and $1\frac{1}{4}''$. (The sign $''$ attached to a number denotes inches.)

Make A B $1\frac{1}{2}$ in. long. From B, with a radius of $1\frac{1}{4}$ in., describe an arc. From A, with a radius of 1 in., describe an arc cutting the former one in C. Draw A C and B C, which will complete the triangle of the required dimensions.

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* To "produce" a line means to carry it on further, or to make it longer in the same direction.

† A spur wheel is one in which the teeth are of iron, cast or cut in the rim; a cog wheel has wooden teeth mortised into the iron rim, this is used principally in mill-work.

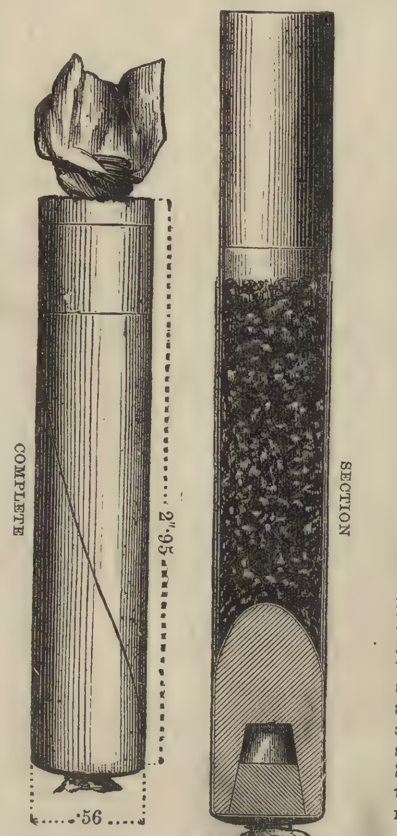
* For full instruction concerning the modes of drawing the various forms of teeth of wheels, the student is referred to the lessons on Technical Drawing.

WEAPONS OF WAR.—II.

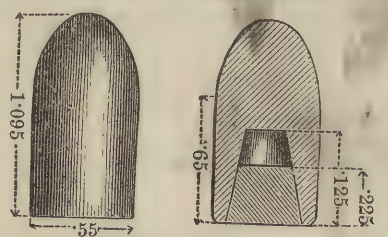
BY AN OFFICER OF THE ROYAL ARTILLERY.

FIRE-ARMS.

THE division of our subject which we have now to consider is the important one of fire-arms. We have seen how the introduction of fire-arms has had the effect of pushing side-arms into the background, how each successive development of fire-arms has by so much reduced the practical value of swords, and spears, and lances, and the like. We have noted also that the tide of improvement has always set in the direction of increased range, increased accuracy, increased destructiveness, increased rapidity of fire. These are the elements of the problem which the gun-maker has for several centuries been striving to solve, checked, however, and circumscribed in his action by the practical considerations which military necessities impose. Thus the exquisitely accurate match-shooting rifles which we see at Wimbledon, with all their refinements for ensuring good shooting—the carefully weighed charges, each in separate bottles, the delicate sights, the light triggers, have never come in for military use, because they fail in the first element of a military arm—simplicity. Again, the far-reaching Metford rifle, with which good practice has been made at 2,000 yards, is not a possible military weapon because of its refinements, and because also of its weight, and of the heavy charge which it requires. Many of the ingenious breech-loaders, in the production of which unhappy inventors have spent their time, their brains, and their money, fail altogether—despite their points of excellence and their rapidity—to satisfy the simpler wants of the soldier. But although let and hindered by these considerations—although continually being turned back from the dazzling path of ideal excellence, and warned out of the dangerous byeways of theoretical refinements—although continually being reminded of the necessity of keeping to the somewhat tame and dusty high-road on which the soldiers are soberly tramping—a road which to some probably appears as straight and dull as those famous military roads of the Romans—despite these restrictions, the gunmaker has succeeded in making very considerable advance in the direction required.



CARTRIDGE USED IN ENFIELD RIFLE.



BULLET USED IN ENFIELD RIFLE.

For many years the arm of the British soldier was a smooth-bore musket, familiarly known as "Brown Bess." This arm had a barrel of about three-quarter inch diameter (·753 in.), and threw a spherical leaden ball, which weighed 483 grains, with a charge of four and a-half drams of powder. It will easily be understood that such an arm was neither accurate nor far-reaching. The charge of powder was large enough, it is true, to project the bullet with a high velocity, but the size of the bullet caused it to meet with great resistance from the air, and thus soon to lose its velocity, besides being liable to be easily deflected. Moreover, being fired from a smooth-bore barrel, it was subject to all the disturbing causes common to smooth-bore projectiles. Among these causes may be prominently named:—(1) windage, which is the difference between the diameter of the bullet and that of the bore, and which, by allowing the passage of the gas over the bullet, causes it to proceed through the bore with a sort of bounding motion, and to leave it in an accidental direction, according to the position of the last impact against the bore; (2) irregularity of form and surface of the projectile; and (3) eccentricity of projectile. The result of these accumulated defects was that Brown Bess, although it would range effectively up to about 200 yards, could hardly be depended upon for even approximate accuracy up to half that distance. There used to be a saying among soldiers that if you fired at the church, you might think yourself lucky if you hit the parish! The smooth-bore musket is not to this day entirely obsolete in our army. For example, the native infantry regiments in India are armed with a smooth-bore musket, which is in some respects superior to "Brown Bess," and has a smaller bore (·656 inch). The native Indian police have also smooth-bore carbines; and some of our coast-guard are still armed with smooth-bore pistols. Indeed, in some distant colonies we believe that even "Brown Bess" herself may still be found.

After Messrs. Minié and Delvigne had shown how, by the adoption of a conical expanding bullet, an effective military rifle might be made, several of the old smooth-bore muskets were rifled with three grooves, and re-issued as rifled muskets—chiefly for naval use. By this means the weight of the bullet was increased to 825 grains, and the range, accuracy, and effective power of the arm were immensely improved. Compared with Brown Bess plain, Brown Bess rifled was an excellent weapon; although in these days of small bores we should smile at a bullet three-quarters of an inch in diameter. The first rifled arm possessed by the British soldier was the Brunswick rifle. This arm had two grooves, and fired a belted ball, which was covered with a patch, the grease upon which, according to Mr. Kaye, determined the outbreak of the Indian mutiny. The bullet weighed 555 grains. The loading was tedious and inconvenient, owing to the belt on the ball having to be carefully adjusted in the groove, and to the great amount of friction; and the weapon, although vastly superior in range and accuracy to the smooth-bore, was comparatively inefficient as a rifled arm. Our rifle regiments and sharp-shooters were armed with it. The Sikh regiments in India are, if we mistake not, still armed with the Brunswick rifle.

But the really important improvement in military fire-arms was due to the labours of Messrs. Minié and Delvigne. We by no means wish to underrate the exertions of other workers in the same field; and prominent among those who laboured to bring into notice the principle upon which the success of Messrs. Minié and Delvigne depended, was Captain Norton, who unquestionably invented and exhibited at Woolwich, as far back as 1823, an elongated expanding shot and shell, identical in principle with the Minié bullet. But it was not until 1851 that the Minié rifle was introduced. The arm was rifled with four grooves, and was intended to fire a conical leaden ball with a hollow in the base, into which was fitted an iron cup. The object of this arrangement was to enable the bullet to be readily loaded, the diameter being less than that of the bore, while by the action of discharge the iron cup would be driven forward into the conical hollow, expanding the bullet. A French colonel named Thouvenin had tried to accomplish the same object in a different way. He placed a small iron pillar or *tige* at the bottom of the bore, and on to this the bullet was rammed until it was expanded. The *carabine à tige* was used by the Chasseurs d'Afrique in 1846 in Algeria, but it was obviously open to some strong objections, such as the liability of the *tige* to become bent or broken, the delay in loading, the want of uniformity in expansion, and the disfigurement of the bullet. The

Delvigne-Minié system was a great improvement on this. The loading was effected almost as easily and rapidly as in a smooth-bore; and the expansion of the bullet depended not upon the exact amount of force or hammering given to it by the soldier, but upon the pressure exerted upon the iron cup by the powder gases at the moment of discharge. The arm as at first introduced was, however, open to some practical objections. In the first place, the iron cup was found liable in some instances to be blown through the bullet, which was left a distorted cylinder of lead inside the barrel, the weapon being thus rendered for the time unserviceable. In the next place, the calibre was too large for accurate long-range shooting—viz., ·702 inch. The weight of the bullet was also objectionably great from a military point of view, being 670 grains. With so heavy a bullet the soldier, if provided with a sufficient supply of ammunition, was inconveniently over-burdened. So, in 1853, a modified Minié rifle was introduced, with a bore of only ·577 inch, and three grooves, which fired a bullet of 530 grains with 70 grains of powder. The iron cup was replaced by a box-wood plug. The reduction in the weight of the arm with sixty rounds of ammunition was three pounds. This was the famous Enfield rifle—the weapon which won Alma and Inkermann, and which at this moment, whether in its muzzle-loading or converted breech-loading condition, is the arm of the greater part of our regular army and reserve forces. But, since the introduction of the Enfield rifle in 1853, several improvements have been made in the ammunition, which have greatly increased the efficiency of the weapon. The two most important of these improvements were, the substitution of bees'-wax for a mixture of bees'-wax and tallow, for the lubricating material; and the reduction in the diameter of the bullet. Both these changes were suggested by Colonel (now Major-General) Boxer, and contributed in an important degree to the efficiency of the ammunition and the arm. The adoption of bees'-wax was recommended on the ground that in hot climates the tallow melted, leaving the rifle unlubricated, besides which the acid in the tallow caused the corrosion of the bullets. The wisdom of adopting pure bees'-wax was stoutly disputed at the time, and has been frequently disputed since. But repeated experiments and inquiries have fully established the efficiency of bees'-wax, and in the advertisement which was issued to the competing gun-makers in 1866, it was laid down that "wax on the bullets is indispensable;" and the evidence which the late committee on small-arms took upon this subject led them to lay down positively that "the lubrication should be pure bees'-wax, as best adapted to withstand variations of climate and long keeping." This is a practical point upon which it seems important to insist. Inventors of ammunition are very fond of submitting fancy lubrications of their own, and it is well, therefore, that it should be distinctly understood that the question of lubrication for military small-arm ammunition has been most fully and patiently considered, and decided definitively in favour of pure bees'-wax. In the Royal Laboratory at Woolwich, the greatest care is taken to ensure the perfect purity of the bees'-wax, which is all subjected to a careful chemical examination.

The second important change which was made in the ammunition was in the reduction of the diameter of the bullet. It was found in India, during the mutiny, that great difficulties occurred in loading, owing to the size of the bullet, which was at first fixed at ·568 inch, leaving a windage of only ·009 inch—quite insufficient, when the rifle became foul, to admit of easy loading. Many instances occurred in which loading was almost impossible. The men were seen striking the ends of their ram-rods against walls and trees, to drive home the bullet, and the evil was so serious as to have threatened at one time to lead to the abandonment of the Enfield rifle. But some experiments, which were carried out by Colonel Boxer, showed that it was possible to reduce the diameter of the bullet considerably without affecting the accuracy of shooting. He found that a reduction of diameter from 0·568 inch to ·55 inch (giving a windage of ·022 inch) might be safely made, and the loading difficulty was thus completely overcome. Other minor changes have been made, as, for example, the addition of a cut through the paper surrounding the bullet, in order to cause the paper to disengage itself from the bullet in flight; the adoption of an improved powder, more uniform in its action, and better adapted to secure the just expansion of the bullet; the substitution of a baked clay plug for one of box-wood, which, as before stated, has superseded the iron cup of the original Minié. The iron cup was given up because it was liable to be blown through the bullet; the box-wood plug was given up on account of the cost of box-wood; and the clay plug was adopted as being inexpensive and efficient. The part which the plug plays in the action of the bullet must be noticed. It is generally spoken of as the expanding agent. This is true to a certain extent; but the expansion can also be secured without any plug. In the Pritchett bullet, for example, which for some short time was used with the Enfield rifle, there is only a shallow hollow, and the expansion is due partly to the action of the gas within this hollow, and partly to the "upsetting" of the bullet, which is due to its inertia. Other bullets—the Whitworth, for example—depend entirely upon the "upsetting" or "over-taking" action. But the plug serves a further and important purpose. It is a supporting as well as an expanding agent. The Pritchett bullet was found to foul, from the simple reasons that the expansion was not so promptly effected as in a plugged bullet, and thus a rush of gas over the bullet became possible, and that when the barrel had become foul, the expanded sides of the bullet, having no internal support, collapsed on coming into contact with the fouling deposit. The plug, therefore, serves a threefold purpose:—1. It ensures the expansion. 2. It makes that expansion so prompt and rapid that the chance of an escape of gas over the bullet is diminished. 3. It supports the expanded sides when the rifle has become foul.

The construction of the Enfield rifle cartridge is shown in the illustrations in the preceding page. It consists of a hollow rolled cylinder of paper, or rather a double cylinder, since the part which contains the powder is a separate cylinder contained in the outer envelope, by which the bullet is attached. The lubrication is applied on the outside of the paper which surrounds the bullet—up to the shoulder of the bullet—which, as every rifle volunteer knows, is loaded with the paper upon it, the top of the cartridge being first torn off, the powder poured into the barrel, the papered bullet inserted in the muzzle, the rest of the cartridge being torn off and thrown away, and the bullet rammed home. The ease of loading with the ·55-inch bullet is so great, that in a clean arm it is possible to load without the ramrod, by striking the butt against the ground.

The bullets are made of perfectly pure lead, the purity of which is tested by chemical analysis. Any impurity tends to alter the weight and to affect the expansion, and thus to spoil the shooting of the arm. The bullets are all made by compression—the lead being first squirted into long rods—and then formed in a machine, which is one of the sights of Woolwich Arsenal, into bullets. The weight of each bullet, with the plug, is 530 grains; and the accuracy of manufacture is so great that the working limits are only two grains over and under the mean weight. The charge of powder is seventy grains. The Enfield rifle is capable of shooting with great accuracy up to about 800 yards, and good practice has been made with it occasionally at longer distances. But 800 yards may practically be regarded as the extreme limit of accuracy of a bore so large as ·577 inch, unless the weights of bullet and powder were unlimited, which, in view of the soldier's requirements, of the quantity of ammunition which he has to carry, and of the amount of "kick" or recoil which he can endure, they cannot be. We have omitted to mention that the pitch of rifling of the Enfield is one turn in six feet six inches; the grooves are ·235 inches wide, and ·005 inch deep at the muzzle, and ·013 inch deep at the breech. The weight of the arm is as nearly as possible nine pounds. The weight of sixty rounds, packed for service, with the proportion of ninety caps, is about five pounds eleven ounces. The same ammunition is used with all muzzle-loading rifled muskets of ·577 bore. A similar cartridge—differing only in the weight of the charge of powder, which is reduced to two drams—is used with all muzzle-loading carbines of ·577 bore. The carbines and the short rifles are for the most part rifled with five grooves, and a pitch of one turn in forty-eight inches. This disposition of rifling is more favourable to accuracy than the three grooves and slow pitch. Some oval-bore Lancaster rifles are in use in the service. This rifle has no grooves. The bore is oval, and the oval being disposed spirally along the barrel gives the necessary spin to the bullet. The oval is at muzzle, major axis = ·593 inch; minor axis = ·577 inch. At breech, major axis = ·598 inch; minor axis = ·580 inch. The same ammunition is used with the Lancaster as with the Enfield rifle. The shooting of the Lancaster is, however, decidedly superior.

MINERAL COMMERCIAL PRODUCTS.—IV.

II.—MINERALS PROPER.

COAL.

COAL is a mineral substance very generally diffused throughout the earth's surface; it occurs of different geological ages in various parts of the world, but by far the greater proportion of valuable workable coal is derived from the Carboniferous series of formations. Good workable coals are obtained in the Lias and Oolite; brown coals and lignites are of Tertiary age. Coal consists of vast collections of carbonised vegetable matter, impregnated in varying degrees with the pitchy and resinous substances now so characteristic of the fir family. Peat bogs in superficial beds present perhaps the first stage in such a change. These masses of vegetable matter, though containing much water, can be made available for house fuel, fuel for manufacture, very fair charcoal, and for the extraction of naphtha, paraffin, tar, etc. In the presence of an abundant supply of coal, peat cannot be economically employed, but it is extremely useful where coal is scarce, as in Holland, many parts of France, Germany, and Ireland. A nearer approach to true coal is the lignite, woody, or brown coal. This mineralised vegetable product, like peat, contains a considerable quantity of moisture, and it suffers in quality on exposure to the air. It is a Tertiary deposit, and is found in Breslau, on the Rhine, in Germany, on the Danube, and the shores of the Baltic, in Styria, Tuscany, Nova Scotia, New Zealand, Devonshire, and County Antrim. True coal is very compact, has for the most part lost its woody and fibrous character, and contains a very small quantity of earthy matter. It consists of two principal varieties, the bituminous and the anthracitic. Bituminous coals contain a large proportion of gas, tar, paraffin, and such substances, and burn, therefore, with a brilliant flame. They are, hence, peculiarly adapted for domestic consumption, for gas, manufactures, coke, etc. The bituminous coal richest in volatile constituents is the variety called "Cannel"—in Scotland the "Parrot"—which burns with great brilliancy. Other varieties are splint and cubic coals. A semi-bituminous coal, burning with less brilliancy and rapidity, but affording great heat, is called "steam coal," from its use in furnishing the supplies of steam-vessels taking long voyages. The middle part of the South Wales coal-field (the western is bituminous), and a part of the Newcastle field recently worked, contain excellent coal of this character.

Anthracite coal is very hard and glossy, not soiling the fingers. It is almost pure carbon, containing but a very small proportion of gaseous products. It burns with a very feeble flame, but gives an intense heat. From its comparative difficulty of combustion it was formerly but little used; but by the introduction of the hot-air blast, and other improvements in furnaces, it can be made available for many manufacturing processes, particularly that of the preparation of iron, for which it is now extensively used in Wales (the eastern part of the coal-field being anthracite) and the United States.

Notwithstanding the enormous consumption of this important fuel, the supply will, perhaps, *never* be exhausted. Immense areas in the New World must be added to the still profusely abundant districts of the Old. The coal area of Great Britain and Ireland is about 9,000 square miles, that of the rest of Europe about the same or rather less; and to known deposits in Asia, South America, Australia, and Africa, must be added 150,000 square miles in the United States and Canada.

The following table may not be devoid of interest in showing the gradual but steady increase in the exports of coal from the United Kingdom from 1854 to 1868. The quantities in the second column include all the different kinds of coal, cinders, and culm exported for any purpose whatever in tons, while the third column contains the declared value:—

Years.	Tons.	Dec. Value.	Years.	Tons.	Dec. Value.
1854	4,309,255	£2,127,156	1862	8,301,852	£3,750,867
1855	4,976,902	2,446,341	1863	8,275,212	3,713,798
1856	5,879,779	2,826,582	1864	8,809,908	4,165,773
1857	6,737,718	3,210,666	1865	9,170,477	4,427,177
1858	6,529,483	3,045,434	1866	9,953,712	5,102,805
1859	7,006,949	3,270,013	1867	10,415,778	5,392,452
1860	7,321,832	3,316,281	1868	10,837,513	5,355,791
1861	7,855,115	3,604,790			

The average annual produce of the principal coal districts of the globe, according to a recent return, is as follows:—

	Tons.		Tons.		Tons.
Britain	101,620,000	United States	16,472,000	Sweden	230,000
Zollverein (with lignite)	25,000,000	Belgium	4,000,000	India	370,000
France	11,000,000	Austria	2,270,000	Australia	450,000
		Spain	400,000	China	100,000
				Nova Scotia	651,300

BITUMINOUS SUBSTANCES.

Many bituminous substances are produced in vegetable matter during its conversion into coal; the chief of these are naphtha, petroleum, and asphalte, which are all hydro-carbons of varying proportions, and of an inflammable nature. The bituminous substances are widely distributed, especially in the tropical and sub-tropical regions—a circumstance which evidently indicates that the substances are due to extensively operating natural causes, and not, as usually supposed, to the accidental combination of special agencies.

The modes of occurrence of asphalte deposits seem referable to three principal divisions:—1. In the rocks of igneous origin; this is the case in Cuba, and at Mount Lebanon. 2. In stratified rocks of the Palæozoic and Mesozoic epochs, usually disseminated in a granular form throughout the entire stratum, or issuing from the soil, or exuding from fissures in the rocks, in the form of springs of petroleum, naphtha, etc. 3. In rocks of Tertiary age, usually accompanied by lignite or brown coal. These are the most abundant sources of asphaltic substances, and include those of Pegu, Trinidad, etc.

Naphtha is a transparent and nearly colourless fluid, burning with a copious flame and strong odour, and leaving no residuum.

Petroleum is dark-coloured, and thicker than common tar. It rises in immense quantities from some of our coal-beds, and impregnates the earth so as to form springs and wells. Petroleum springs contain a mixture of petroleum and the various substances allied to it: they occur in abundance in Modena and Parma, Italy, Persia, Canada, United States, etc., but the most powerful are those in the province of Pegu, in the Burman Empire. In many parts of the world petroleum is now the most abundant source of photogen and paraffin. The petroleum or rock-oil of the United States is refined for illuminating purposes, while in the crude state it is a good lubricant.

Bitumen, or *Asphalte*, is an inspissated mineral oil, of a dark-brown or black colour, with a strong odour of tar; the most valuable is hard, brittle, of a brilliant lustre, and eminently conchoidal fracture; a variety occurs of the consistency of jelly, and bearing some resemblance to soft india-rubber. It is very abundant on the shores of the Dead Sea, occupies the so-called pitch-lake in Trinidad, and occurs in Cuba, Peru, Mexico, Ionian Isles, Portugal, etc. The Rangoon tar or Burmese naphtha is distilled from a number of volatile hydro-carbons, chiefly used as lamp fuels; those known as Sherwoodole and Belmontine have considerable detergent power, removing stains from silk without impairing delicate colours. Beds of limestone and clay occur impregnated with bitumen, and from such paraffin is distilled in Britain, Germany, France, Austria, etc.

Jet, so much prized in the manufacture of ornaments for its intense blackness, its lightness, and its beautiful polish, is a variety of lignite highly bituminised and free from earthy impurities, and resembles Cannel coal, but it is blacker, and has a more brilliant lustre. It occurs in the Upper Lias of Whitby, in which it is very abundant, in Languedoc, Asturias, the Alps, Gallicia, and Massachusetts. The value of the jet manufacture of Whitby is about £20,000 per annum.

Amber is a fossil resin, the origin of which has been traced to coniferous trees, and is found in alluvial gravels. It occurs, too, in the Cretaceous marls of France and Germany. It is procured from Prussia, the shores of the Baltic, the Adriatic and Sicilian shores, and from Japan, Madagascar, and the Philippine Islands.

Gum Copal is a semi-fossilised gum found in a sandy soil in the hilly districts all along the coasts of Angola, the total yearly export of which from all the districts of Angola is estimated at 2,000,000 lb. A gum copal is obtained under similar conditions from Sierra Leone and Zanzibar, the origin of which, as well as that of Angola, is still unknown.

Some copal resins are exudations from living trees, as that furnished by *Guibortia copallifera* of Sierra Leone, and others.

TECHNICAL DRAWING.—V.

FREEHAND DRAWING (*continued*).

AGREEABLY with the plan already laid down, to practise freehand concurrently with linear drawing, the following figures are given as examples of objects which are so nearly flat that they can be rendered by their outlines only, without a knowledge of perspective, which the student has yet to acquire, and in which lessons will be given further on.

Fig. 25 represents a pair of compasses, such as are commonly used by joiners. In beginning this simple subject, draw a horizontal line, and on it erect the perpendicular A B.

From A set off A C and A D, and joining B C and B D, complete the triangle C B D.

The apex of this triangle will be the centre of the rivet. Draw the small circle around this point, and the larger circle for the head of the compasses.

Next draw the lines E C and F D, which form the outer sides of the instrument, and which are slightly curved. The inner sides to G and H are straight, and are portions of the triangle previously drawn. The lines I and J correspond with the outer edges, of which, indeed, they form portions when the compass is closed.

Fig. 26 is an outline of a shaping-knife, and but very few instructions will be required for copying it. Draw a horizontal line for the back of the tool, and two lines at right angles to it, which are to form the centre lines of the handles. The instructions given in relation to the handle of the screwdriver will serve for these as well; but you must be careful to get the two handles *precisely* alike. When this is accomplished, draw the edge of the blade parallel to the back, and then complete the curved portions by which the blade is united to the handle.

Fig. 27 is a drawing of a tool with which the carpenter will be well acquainted; but it often happens that although we may have seen a thing daily, we have never noticed the peculiarities in its form which may strike a casual observer.

This habit of observation is one of the beneficial results of mental training, and no instruction is so likely to induce it as drawing; for a man who accustoms himself to draw from objects, will, in the old-fashioned words, "walk through the world with his eyes open," and every day, nay, every hour, will add to his stock of information, and of his power of delineating the objects he sees. To workmen this is especially important, and practice in drawing tools will be both interesting and useful.

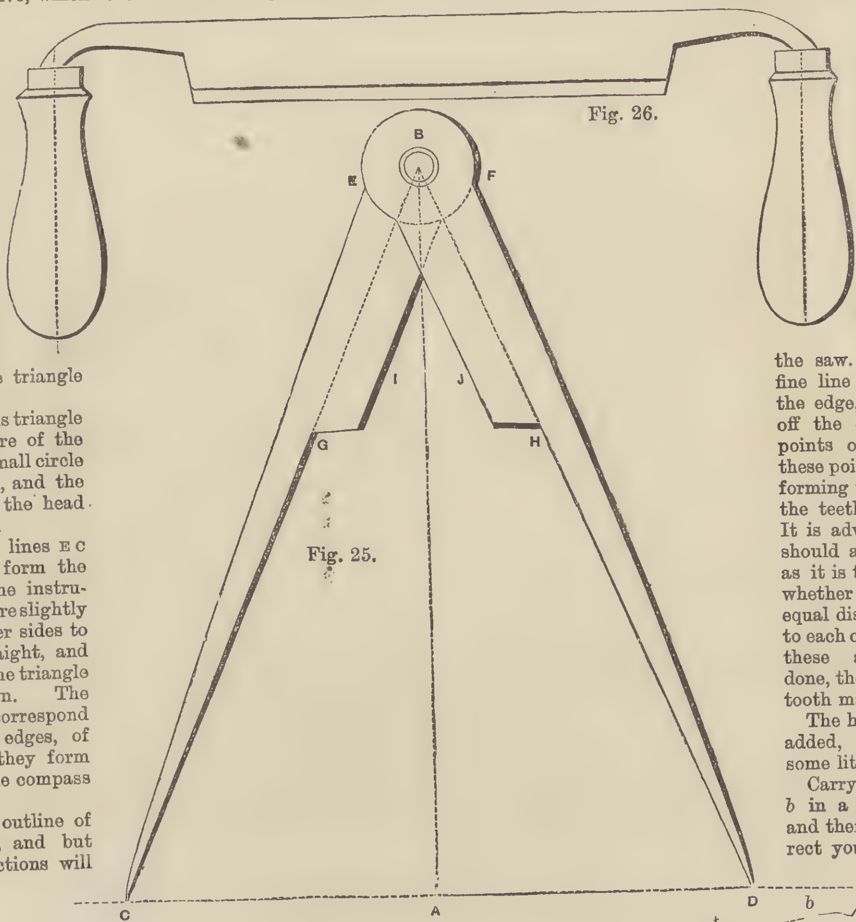


Fig. 26.

Fig. 25.

In the figure now before us, the long oblique line, *a b*, forming the back of the saw, is to be drawn first, and then *b c* at right angles to *a b*. At *a*, a short curve will lead to the line *d*, which is a continuation of the back; thence the line turns to *e*, forming the end of the saw. From *e* draw a fine line on which to rest the edge, and on this set off the distances of the points of the teeth; on these points the short lines forming the front edges of the teeth are to be drawn. It is advisable that these should all be drawn first, as it is then easier to see whether they are all at equal distances, or parallel to each other, or not. When these are satisfactorily done, the back line of each tooth may be drawn.

The handle must now be added, and this requires some little care.

Carry on the line from *b* in a curve downwards, and then the eye must direct you in following the form until you come to *g*. Returning to *f*, draw *f h*, and follow the curve to *i*; next, the under side of the handle, *i j*, then the curve *g j* will complete the external form of the handle.

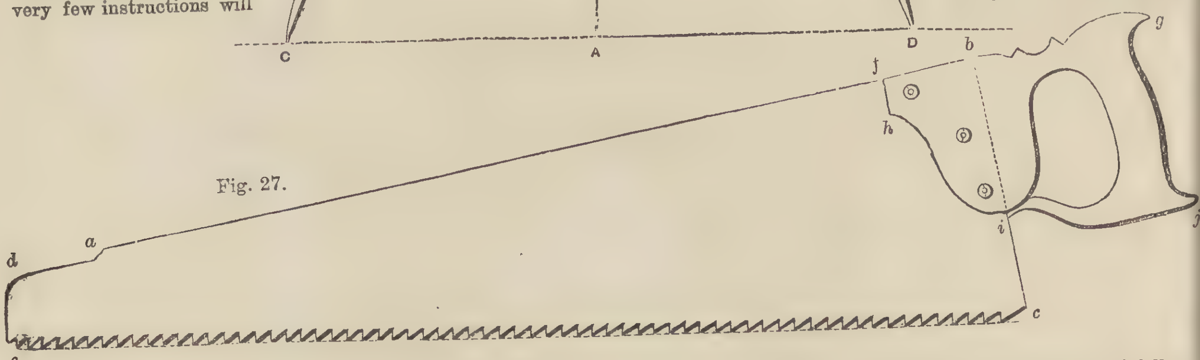


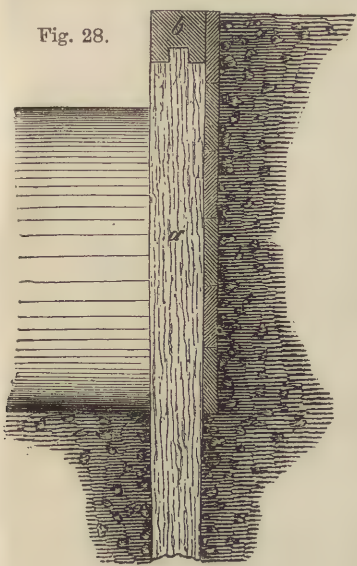
Fig. 27.

Now return to the point *i*, and carry the curve round so as to form the inside of the handle. The screws are to be drawn next, and no workman will require to be reminded that these must be placed *inside* the line *b c*; in fact, it was to make sure that the screws should be rightly placed that the whole line *b c* has been drawn, whilst only the portion *i c* is required.

Now, all saw-handles are not precisely alike, and further, their edges are bevelled off, so that at *f h i*, etc., double lines would be

seen. All this is, however, omitted here, so as to keep the example as simple as possible. When, however, this is mastered, the student is advised to make a drawing *from his own saw*, and having sketched the general form as in the present figure, to fill in any detail he may observe.

Fig. 28.



But he should also attempt to draw it in some other position: for instance, hanging by the handle from a nail in the wall.

Whilst making such a sketch, the paper must be kept perfectly straight in front of the student; but when the form is completed, he should turn it so that it may be in the position of that in Fig. 27, and he will then possibly see many points requiring correction. Still, it is necessary that he should become accustomed to sketching objects in any position in which they may be placed, and this will soon be accomplished by practice and perseverance.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Fig. 28 is the section of a dam, or wall of planks, which confines the soil subject to the action of water. Of course, the strength required for such a dam must depend on the height of the water-level—that is, the wall must be strong in proportion to its height. Fig. 28 is one of the simplest examples of these constructions, and consists of piles, placed at a distance from each other, which must be regulated, first, by the nature of the soil at the back of the dam, and its tendency to press forward; and secondly, by the thickness of the planks employed for the wall, which must be such as to resist their being bent by the force of the soil they confine. Of course, the more such pressure is to be expected, the closer must the piles be placed.

The piles are in the above example connected at the top by a cross-timber, into which they are mortised. The planks are then placed horizontally at the back of the piles, and may be united by the methods shown in previous lessons.

The drawing in this subject is very simple. First, the pile *a*, with section of the cross-beam *b*; next, a line parallel to the inner side of the pile, and at a distance from it equal to the thickness of the planks of which the wall is to be constructed; between these two lines short horizontals are to be drawn, or the joints of the edges shown, according to the method adopted.

Fig. 29 is the section of a dam used in cases where the soil is very swampy in character, or where the external water might pass through fissures in the bed of the stream, and so enter the foundation at a lower level than the bottom of the wall adopted in the previous case. The plan here adopted is to drive in the strong piles *a*, and to connect these by the cross-timber *b*, partially sunk and temporarily fastened on to them. Another timber, *d*, is then to be laid on the bed of the water, parallel to *b*, and this is also to be bolted on to the piles, and at the back of these the wall of perpendicular planks, united at their edge by one of the methods already shown; or sheet-piles, *c*, may be used—these are driven down far below the bed of the water, as the circumstances may require.

Fig. 29.

Each of these planks having been driven until it reaches more solid soil, the strong rail, *e*, is placed at the back of them, and a bolt passing through *e*, *b*, and *a* binds them all firmly together; the heads of the planks are then sawn off to one level.

Fig. 30 is a section of one of the walls of a coffer-dam. A coffer-dam may be defined as a water-tight wall, enclosing the site on which the pile of a bridge or other structure surrounded by water is to be erected.

Coffer-dams are, of course, constructed of a strength sufficient to bear the pressure of the water from without, which would sometimes damage, or even demolish them altogether, were it not that they are secured by struts, and otherwise strengthened.

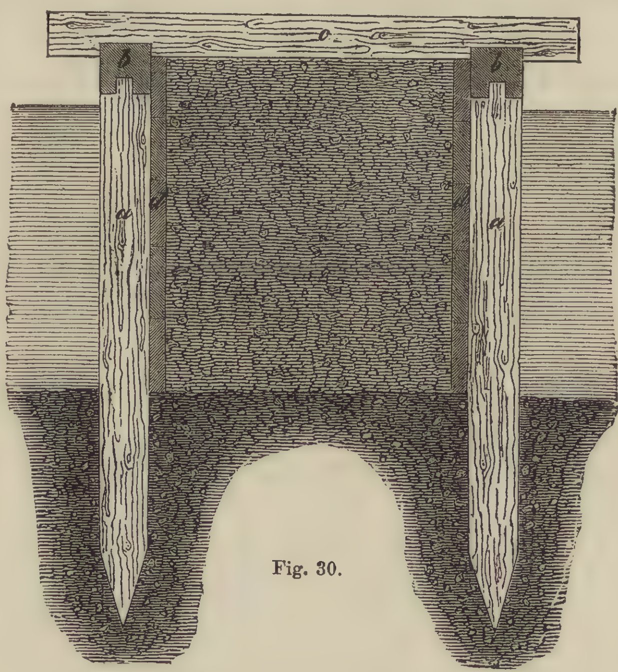


Fig. 30.

The coffer-dam, of which Fig. 30 is a section, is one of the simplest used; it consists of a double row of piles, *a*, *a*, united by the head-piece, *b*, the rows of piles being kept at equal distances from each other by cross-timbers, *c*, which, as will be seen in the illustration, act as a cramp in preventing them either spreading outward, or being pressed inward.

Walls of planks, *d*, *d*, are next attached to the inner sides of the piles, the internal space being then rammed with clay, etc.

In drawing this and the future examples, the students are reminded that they are arranged progressively, and that as the subjects increase in difficulty, additional care and accuracy are required. Again they are urged not to be content with their work being *nearly* right. To carpenters and joiners this accuracy is especially important, for the different parts, got out by separate workmen, must, when required, fit exactly to each other, and this would not be the case if either one of them had been careless or inaccurate. This exactitude is only to be obtained by accustoming yourself, from the very outset, to measure with care, and to draw your lines exactly through the proper points.

TECHNICAL EDUCATION ON THE CONTINENT.—III.

By Ellis A. Davidson.

MODELS USED IN TEACHING ANIMAL PHYSIOLOGY—THE POLYTECHNIC SCHOOL IN HANOVER.

The great number and variety of the sets of models for teaching practical art which are published on the Continent, show their extensive use in the schools and the appreciation of the teachers. Opportunities will be taken, when describing the leading schools, to give some account of the models and teaching apparatus employed. Such methods of illustration are not, however, confined to the mechanical arts, nor is the education of the workman on the Continent limited to the precise branches which he may require in his occupation. This arises from the circumstance that he has overcome the rougher and more irksome portions of study in his youth, and thus in maturer years he has time and mind to spare, so that as he passes through the garden of this world, he need not spend all his time in simply gathering sticks for his immediate use as fuel, but retains enough of the freedom or elasticity of youth to rejoice at the sight of the lovely flowers which ornament his path, to gather and examine into their wonderful structure; he has time to study the elaborate construction of his own frame, and the natural history of the bird which gaily floats past him in the air. These studies tend to elevate and refine; they give the life of an artisan an aim beyond hewing wood and drawing water; they give him sources of happiness and amusement which he can take up after his day's toil—amusements which can be pursued *at home, and in which his wife and children can partake*—amusements which, as he walks to his work next morning, afford him happy reflection, thus causing him to meet his fellow-men with a cheerful and contented mien: how different from that of the man who in his shopmates only sees the boon-companions of the previous evening's carousal, on the details of which each in his sober moments looks back with shame! There is more religion, more morality, brought about by this popularising of science than many persons think. The man who has made the works of God his study during the week, will not waste the morning of the Sabbath day in listless idleness and the evening in smoking and drinking. He will look upon it as a day when, together with his family, he may undisturbedly contemplate God's works, and walk hand-in-hand to the house of prayer, realising the truth of the text, "Man doth not live by bread only, but by every word that proceedeth out of the mouth of the Lord doth man live." The subject of physiology is one of importance in the instruction of working men. We see many who, when a hinge of a door in their house happens to have given way, a board of the floor become loosened, or an article of furniture out of order, bring home with them the necessary screws, nails, etc., and at once set about repairing; but, owing to the neglect in their education, they know nothing of the "house they live in," the body in which their Creator has placed that spirit with which he has endowed them, and for the care of which he holds them responsible. They will learn that temperance in food and drink, cleanliness, and proper exercise will double the value of their own lives and those of their children.

Human physiology and zoology ought to form portions of general education, and no doubt will become so in this country, as they are on the Continent, when our teachers shall have become duly qualified; and for this purpose we require such models as are about to be described. A learned English professor, in reviewing the study of physiology in a school, remarked that "the teacher should obtain heads, hearts, etc., of sheep, oxen, and other animals, and dissect in the presence of the boys." Now it is scarcely necessary to say that this is wholly impracticable in schools for boys, and difficult of accomplishment in those for adults. This obstacle is in a great measure overcome by the excellent—it may be said wonderful—models of natural objects used in the schools on the Continent. Foremost amongst these rank the "clastic anatomical models," by Dr. Auzoux, of Paris. The term "clastic" is derived from the Greek κλαω, *I break*, and is applied because the models are composed of an immense number of separate pieces, each of which may be removed as in a real dissection, and can be replaced. Amongst these there is a complete life-sized model of the human body, composed of 130 parts, all of which may be detached, thus exposing to view upwards of 1,000 objects, comprising the leading features of the bony, muscular, nervous, arterial, and venous systems; the heart, brain, lungs, viscera, etc., all coloured to nature. This is, of course, a most complex object, adapted for a very high order of teaching, such as would be pursued in a technical course prescribed for persons who are subsequently to follow the study of medicine, and serves admirably to prepare for, though of course it cannot supply the place of, absolute dissection; but as it illustrates perfectly the descriptions contained in the most complete treatises on anatomy, it is invaluable to the lecturer. This model may also be had of a smaller size ($3\frac{1}{2}$ feet high), but containing the same number of parts as the one before-mentioned. The model adapted for teaching human physiology in schools and science classes, where the instruction is of a more general character, is 5 feet 9 inches high. It represents on the one side the muscles and vessels of the superficial layer, and on the other the muscles, vessels, and nerves of the inner layer, besides other organs, as in the complete model. This, too, is used of a smaller size.

Another model shows the eye greatly enlarged, with parts of the orbit, the muscles, vessels, nerves, membranes, vitreous humour, crystalline lens, etc.; also models showing sections of the heart, brain, etc. Next we find a complete model of a horse, size of life, divisible into 200 pieces, comprising more than 3,000 minutiæ; a model of the foot of a horse, showing the disposition of the hoof, of the vessels, nerves, etc., all the parts separating; another, illustrating the affections of the bone in the horse, showing from the commencement to their full development the diseases known under the names of splints, spavins, etc. The boa constrictor, 7 feet in length, with its complete anatomy; the silk-worm, 2 feet 6 inches long, showing the alimentary canal, muscles, nerves, trachea, and the apparatus for the formation of the silk; bees, magnified to about 3 inches in length, showing the male, queen, honey, and wax bees, the honey cells, the development of the larva, etc. We also find in use a set of models by the same author for exhibiting the functional distinctions of mammalia, birds, reptiles, fishes, and protozoa, and the different orders into which they are divided. Dr. Auzoux has also published a set of very large models of plants, showing the most minute portions of vegetable organisation in the various stages of development—the seed, flowers, and fruit. The whole collection is of infinite interest, teeming with instruction, whilst the size of the models is such as to enable the lecturer to explain the position and use of even the smallest organ; but, unfortunately, the prices of these models is necessarily so high as to place them far beyond the reach of most schools or institutions. Were, however, a workmen's "verein," or union, formed, single models might be obtained, which could be circulated to the classes in connection with the parent institution, in the same manner that books, pictures, etc., are lent to local schools by the Government Department of Science and Art. It is impossible to understand clearly the action of any machine without a knowledge of its various parts; and as both the animal and vegetable structures are by far more complex, and contain more minute parts, each having its special function, it is certain that physiology cannot be successfully taught without tangible illustrations such as these, which, as already said, are second only to absolute dissection.

These models have been thus fully described, and their high price hinted at, in the hope that some of the skilled workmen who read these papers may be induced to attempt an imitation of at least a few of the simpler ones; and even in this admirable set there are omissions which possibly might be supplied by Englishmen. Amongst models which may be suggested to be made are longitudinal and cross sections of bone, showing the Haversian canals; a joint, such as that at the knee, showing the synovial bursa (or, as machinists would call it, the "oil cup"), by means of which the joint is lubricated or greased; it would also be useful to have a model of a section of the skin, with the perspiratory glands, etc., showing the ill effects of the want of cleanliness in allowing the pores to become stopped up. The material employed might be plaster of Paris, papier-maché, gutta-percha, or composition of various kinds, coloured and varnished. The fine exhibition at the Agricultural Hall, London, in 1870, well showed what artisans could do; and this suggestion is made with every hope that it will be well received and acted upon.

Another set of models for teaching botany is manufactured

in Breslau, and is, as it deserves to be, very extensively used. It consists of buds, flowers, fruit, etc., made of thin metal coloured to nature, mounted on stands, and arranged according to both the Linnæan and natural systems. Amongst the models of the first series are plants exhibiting the difference between monocotyledons and dicotyledons, etc., the second series shows the germination and development of various leading families of plants. Another series is, we hear, in preparation, which, when a knowledge of the previous sets has been acquired, will be of immense service in the study of economic botany. In this series will be given the leading plants used in trade, manufactures, food, etc., and will thus enable the teachers to show imitations of objects when they would be out of season, and to show the natural growth of such as only reach this country in a dried or manufactured condition.

The most extensive set of illustrations of objects of natural history is one which, originating in Prague, has spread far and wide. It consists, in the first place, of the real skeletons of animals, bleached and jointed with wire; next, the animals complete, stuffed. Then follow such as a squirrel, bird, crab, lizard, snake, frog, fish, etc., the blood-vessels, etc., being injected with coloured fluids to show the circulation; and this set is completed by collections of animals preserved in spirit. Another section comprises dried specimens of animal life, and contains such creatures as the lobster, the water-spider, various fishes, the sea-urchin, sea-star, sponge, etc. Next follow collections of insects, shells, and corals, arranged according to the most modern classification; collections of minerals, crystals, petrifactions, and fossils, either real or imitated in plaster of Paris. This comprehensive set embraces also 100 models in plaster of polycystinæ and foraminiferæ (see "Cassell's Animal Kingdom"), each being five or six inches high, and are exceedingly useful in class teaching, being absolute reproductions on an immensely increased scale of these minute microscopic organisms to which we owe so much of the earth's crust. Together with these a technical collection is used; this comprehends, amongst numerous other objects, skins, furs, and leathers; wool, raw and manufactured; silk, and silk fabrics; cotton, raw and manufactured; linen goods, paper, woods, etc. This collection differs from the miscellaneous one used in English schools under the name of "object boxes." In one moderate-sized case there are above 600 substances, contained in 300 cardboard boxes, and about 140 others, either placed in bottles or mounted on cards. These placed around the schools, their names and some few particulars being appended, must attract the attention of children, and this silent teaching goes imperceptibly on; and when the right time comes the little pupils do not approach the lessons in fear of difficulty, but are interested in the subjects and anxious to learn about them.

In Austria we also find in use a fine collection of models of fish, all correctly coloured to nature. This is found very useful, for as a rule we see fewer members of the finny tribes than of any other, the knowledge of the form of most of them being in many cases limited to such as belong to the locality. This set places before the pupils well-executed models properly classified, and thus is of material service. In Austria, too, we have collections of seeds, arranged in sunk compartments on trays, like coin-boxes, sets of birds' eggs, cocoons, etc.

Having thus given a general description of some of the appliances used in technical institutions on the Continent, the various educational establishments must now occupy our attention, the models, apparatus, diagrams, etc., employed in each being described in connection with the systems under consideration.

THE POLYTECHNIC SCHOOL IN HANOVER.

This institution, which ranks as one of the most important in Europe, is under the administration of the Royal Commission for Trade Schools (Gewerbeschulen), organised by the decree of the Ministry for Finance and Commerce, dated June 15, 1835.

This royal commission is also charged with the direction of the school for building construction in Nienburg, the higher working school in Hildesheim (höhere Gewerkenschule), and the collective trade schools in the provinces. It is especially the duty of this body to see that the authorised arrangements and course of studies are rigidly carried out—that the school regulations are observed by all concerned, to appoint the teachers in the various trade schools, and to supervise the proper appropriation of the pecuniary resources.

The commission, which is directly under the Minister of the Interior, and by the enactment of September, 1863, consists of seven persons, namely, four members who do not belong to the Polytechnic School, together with the director, one professor, and the principal (syndicus) of that institution.

PROJECTION.—IV.

PROJECTION ON THE INCLINED PLANE.

On referring to the projection of the cube (Fig. 17), it will be seen that it is there represented as if placed with its faces at 45° to the vertical plane, the line of the diagonal of the plan being parallel to the vertical plane. We must now consider the mode of projecting views of objects, at whatever angle they may be placed in relation to both planes.

Let it be required, then, to project the cube when its faces are at 30° and 60° to the vertical, and when it stands on a plane inclined at 26° to the horizontal plane. It may here be pointed out, that in projecting *views* it is necessary to raise the objects at one side, or to place them on inclined planes; for otherwise, as they are supposed to be exactly on the level of the eye, the elevation only (as in Fig. 17) would be seen, but when raised at one side the top becomes visible.

Place the plan (Fig. 35) at the required angles to the intersecting line. Draw the line A (Fig. 36) at 25° above the line. This line represents the edge (or side elevation) of the inclined plane on which the cube is supposed to stand.

Draw the line B (Fig. 35) at right angles to the intersecting line, and from a b c d draw lines at right angles to it, and cutting it in a' b' c' d'.

Now it will be evident that these would be the widths which would be presented to the view of the spectator when looking at the sides a c d from the point C in direction of the arrow, and therefore, if perpendiculars equal to the height of the cube be drawn on a' b' c' d', and their extremities joined by a line parallel to B, D will be the elevation of those sides.

Fig. 36.—Transfer the points a' b' c' d' to the inclined plane (A), and on them construct the elevation as at D. The perpendicular at b is to be a dotted line; for, although known to exist, it would not be seen from C unless the object were supposed to be transparent.

Now, by drawing perpendiculars from the points in the plan, and intersecting them by horizontals from the points correspondingly lettered in the elevation, the projection E (Fig. 37) will be obtained.

It is now necessary to obtain the upper projection of the object—that is, the view from F, looking in the direction of the arrow.

Now it must be remembered that the elevation on the inclined plane is the view obtained from C (Fig. 35). It is therefore necessary that as this elevation has been turned round, the widths of the plan should be turned round also. Take the line e f, which in the plan is at right angles to the vertical plane, and place it (indefinite in length) parallel to the intersecting line (Fig. 38). Draw a perpendicular from a, in the elevation (Fig. 36), to cut e f in a. This gives the plan of the one angle of the top of the cube. From b draw a perpendicular, cutting e f in g, and from g set off on this perpendicular the distance b g' in the plan (Fig. 35), viz., to b. From c (Fig. 36) draw a perpendicular, cutting e f in h; from h set off h' c of the plan—viz., to c. From d draw a perpendicular cutting e f in i. From i set off the length i d of the plan. Join a b c d, and this figure will be the plan of the upper surface of the cube. From each of these points draw lines parallel to I L, intersect these by perpendiculars from the corresponding points in the *bottom* of the elevation, and lines connecting these points will complete the projection of the cube when viewed from above.

SIDE OR END ELEVATIONS.

The last lesson will have shown us that other views besides *front* elevations are necessary. These are called side or end elevations. In objects which are uniform in character, such as the cube (Fig. 37), the elevation of each end may be the same; but in a locomotive engine, a lathe, etc., the end elevations differ materially from each other, and in such cases several

drawings are necessary in their construction and in their projection.

The model shown in Fig. 39 is similar to that given in the first lesson; but the vertical plane, instead of being made of one piece, rotates on hinges at *a b*, and may be brought forward to *c*, so as to be at right angles to both planes.

Let us now place a thin metal plate, *d e f g*, perpendicularly on the horizontal plane, with its surface parallel to the vertical plane; then it will be seen that *h i j k* is the front elevation, and that the view when looking at its edge, in the direction of the arrow, will be the line *l m* projected in the plane *a b c n*, and this is the end elevation. If now this plane be turned back to its original position (that is, rotated on the line *a b*) until it forms a continuation of the vertical plane, and *c* has moved to *c'*, the end and front elevation will appear on the same plane; it will then be seen that the height of *l' m'* is the same as *h j*, and that in its motion the point *l* will have travelled through a quarter of a circle.

If now the vertical and horizontal plane be converted into one flat surface, by withdrawing the pin *r*, the plan and the front and end elevation will be found to be those represented in Fig. 40.

Fig. 41 is the end elevation, and Fig. 42 is the plan of a triangular prism when lying on one of its long sides, its edges being at right angles and its end parallel to the vertical plane; thus the exact shape of the end—that of an equilateral triangle—is presented to view. But when the prism is turned, so that the plan is at an angle to the vertical plane (Fig. 43*a*), the elevation (Fig. 43*b*) becomes materially altered; for as the object has rotated on the point *b*, *a* has receded, whilst *f* has advanced, and the apex, *d*, of the opposite end, which in Fig. 41 was hidden beyond *c*, now becomes visible; the height, however, remains the same as in the original figure.

Fig. 44.—Here the plan *a b e f* is further rotated until its edges are parallel to the vertical plane: the elevation is then shown in the dotted parallelogram, *b c d e*. Let us now raise the prism at one end (Fig. 45), so that its under side is at 20° to the horizontal plane. In this case it will be seen that the prism rests upon the line *e f*, and the points of the end elevation will now become visible in the plan, and if this plan be turned (as at Fig. 46) at an angle (say 45°) to I L, perpendicular lines from the points of the plan intersected by horizontal lines from the elevation will give the projection of the object at a compound angle (Fig. 47).

Fig. 48 shows the plan, and Fig. 49 the elevation of four such prisms meeting at a point, a figure which very frequently occurs in designing or drawing the roofs of houses, churches, etc.

The plan is formed of two figures similar to the plan of the last prism, crossing each other at right angles, and from this the elevation is easily projected.

Figs. 50 and 51 show the projections of the object when placed at an angle to the vertical plane; and Fig. 52 is the development of one of the four parts of which the model is composed. To construct this development on a straight line, set off three spaces equal in width to the sides of the prism, *a' b f a*, and erect perpendiculars from the points. Make these perpendiculars equal to the lines similarly lettered in the plan. Now it will be clear that when two parallelograms, like those forming the plan of the prism, cross each other, they will form four right angles at the centre. Therefore, at *d'* and *e* construct angles of 45°, which will meet in *c* and form the required right angle, and this will complete the under side. Draw *c h* and *c i* at right angles to *e c* and *d' c*, and equal to the altitude of the triangle *g c* in Fig. 41. Join *d' i* and *h e*. Then the right-angled triangles, *d' c i* and *e c h*, turned up at right angles to *a b c d e*, will form the upright sides of the mitre; *i* and *h* will then come together. The triangular end, which is repre-

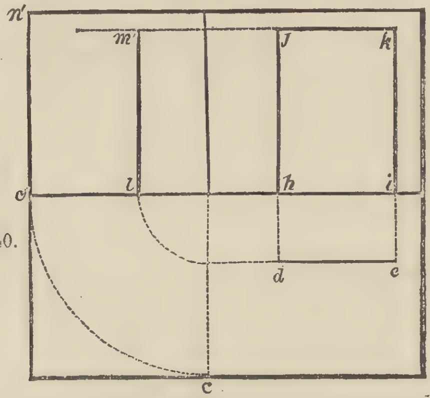


Fig. 40.

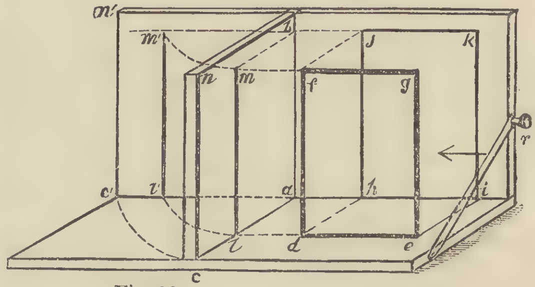


Fig. 39.

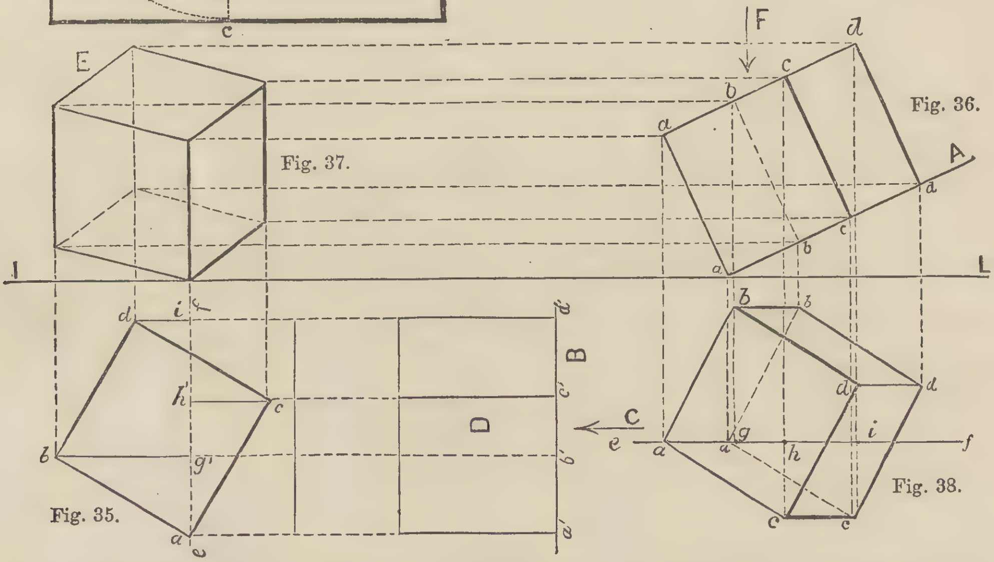


Fig. 37.
Fig. 36.
Fig. 35.
Fig. 38.

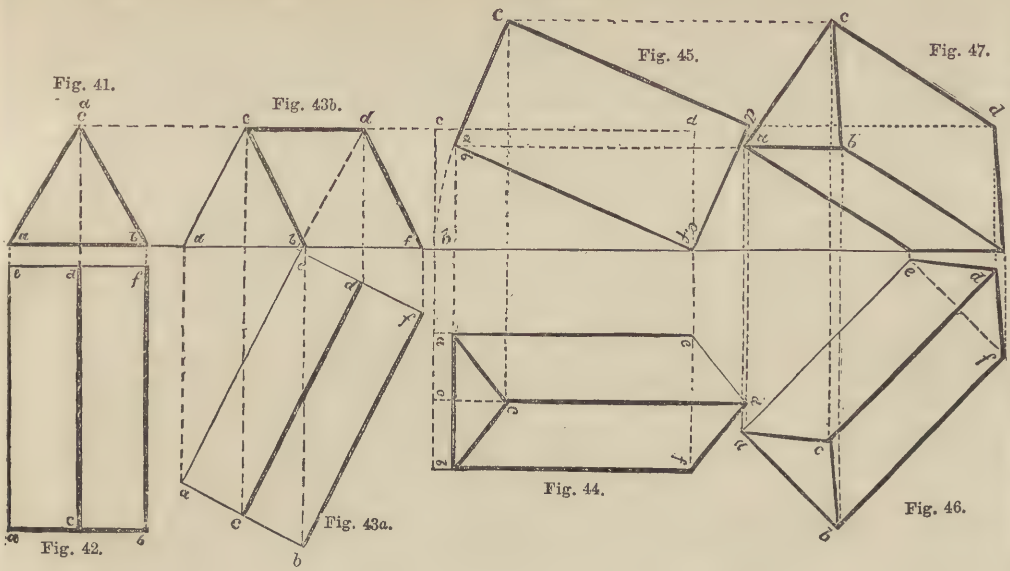


Fig. 41. Fig. 42. Fig. 43a. Fig. 43b. Fig. 44. Fig. 45. Fig. 46. Fig. 47.

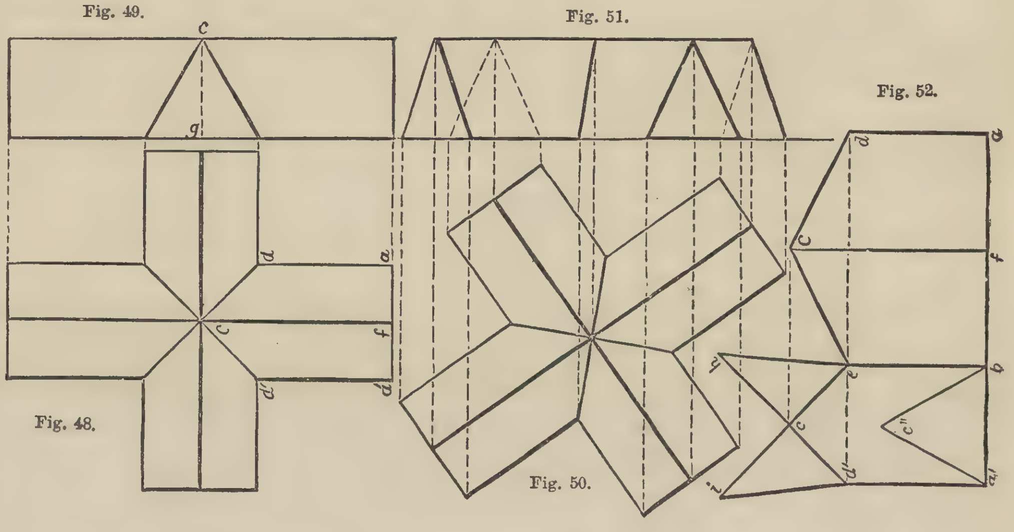


Fig. 48. Fig. 49. Fig. 50. Fig. 51. Fig. 52.

sented as bent down, being now turned upward at right angles to the under side, the two upper sides are to be bent over. Then C will meet *h i*, *f* will meet *c″*, and *d a* will meet *d′ a′*.

THE PROJECTION OF POLYGONS.

In Figs. 53 to 60 the mode of projecting a plane pentagon is shown.

Fig. 53.—Let A B C D E be the geometrical figure when lying flat on the horizontal plane with one edge, A and B, at right angles to the vertical plane; as in all the planes in a similar position, the elevation would be merely a line marking the greatest width, as A C E (Fig. 54).

Now let it be required to construct the plan of this figure, when the plane resting on A B is raised to an angle of 30° to the horizontal plane. Then, as each of the points C D and E will travel through portions of circles, draw a line at 30° at A on the intersecting line, and from A, with radius A C and A E, describe arcs cutting the line in points correspondingly lettered. This, then, will be the elevation. From *e* draw a perpendicular cutting E *f* in *e′*. From C and D draw lines parallel to E *f*. Then perpendiculars drawn from $^{d}_{c}$ in the elevation will cut these last-mentioned lines in *c′ d′*. Join B *d′*, *d′ e′*, *e′ c′*, *c′* A, which will complete the plan of the figure.

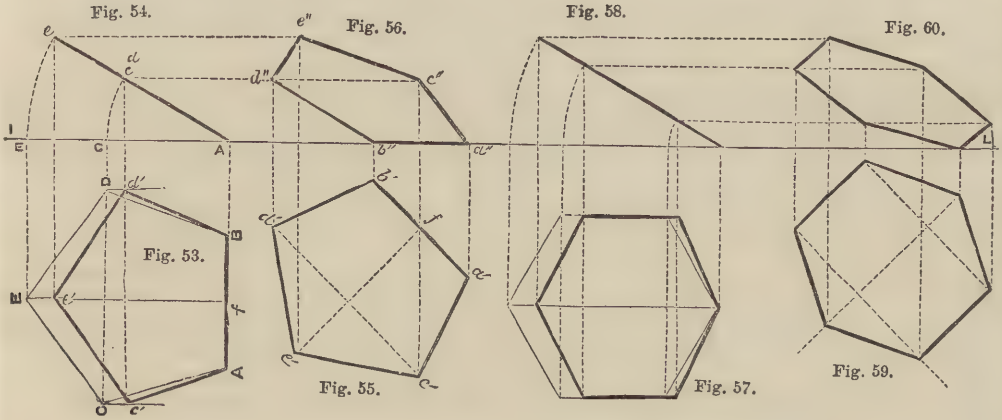


Fig. 53. Fig. 54. Fig. 55. Fig. 56. Fig. 57. Fig. 58. Fig. 59. Fig. 60.

Fig. 55.—Here the plan is turned, so that $a' b'$ is at 45° to the vertical plane, and it will be seen that by drawing perpendiculars from the angles of the plan, and intersecting these by horizontals drawn from the corresponding points in the elevation, the projection of the plane will be obtained. It must be remembered that the pentagon being "regular," * a line joining C and D will be parallel to A B, and will remain so, however much the plane may be raised. Thus, this line $c' d'$ is represented in the elevation by the point $^{d}_{c}$—the line itself being *horizontal* and at right angles to the vertical plane (see Fig. 2, page 8). Now when the object is turned round this horizontal line becomes visible, and the perpendiculars from $c' d'$ intersecting it, give the points c'' and d'', and it will then be seen, that as the line joining these points was horizontal and parallel to A B in the previous figure, it will remain so in the projection; and this will explain the cause of *two* points in the plan coming on *one* line in the projection—a case which will frequently occur in the projection of polygons.

Figs. 57 to 60 show the same process adapted to a regular hexagon when resting on one of its angles, which it is expected the student will be able to work out without further instructions.

ANIMAL COMMERCIAL PRODUCTS.—III.

DIGITIGRADÆ (*continued*).

The *Skunk* (*Mephitis Americana*) is common in North America, especially in the States of Pennsylvania and New Jersey. It is well known for its power of ejecting, when hunted, from a small bag placed at the root of the tail, a very offensive fluid, which produces one of the most powerful and intolerable stenches in nature. This animal is allied to the polecat of Europe. Its fur is soft and black, with two white stripes running from head to tail. The fur is purified by exposure to heat. The Hudson's Bay Company send to Europe annually about 10,000 skins, which are mostly exported to other parts of the world.

The *American Otter* (*Lutra Canadensis*) is aquatic in its habits, and lives principally upon fish, which it pursues in the water. The colour of the fur changes with the seasons: in summer it is short and almost black, but on the approach of winter it alters to a beautiful reddish-brown. The motions of the otter in the water are very easy and graceful. The short, close, fine fur keeps the body at a proper temperature, and the short legs, webbed feet, and rudder-like tail enable it to move swiftly in any direction in pursuit of its agile prey. In 1864, 21,319 otter-skins, valued at £14,461, were imported into this country by the Hudson's Bay Company.

The Sea Otter (*Enhydra marina*).—The fur of the sea-otter is thick, soft, and woolly, and much prized in Russia and China, where it is the fur of royalty; to those countries most of the skins are exported. The animal is found in the North Pacific, from Kamtschatka to the Yellow Sea, on the Asiatic coast, and from Alaska to California, on the American coast. It is a rare animal, and not more than 1,000 skins are annually procured. In 1864 we imported 641, valued at £7,891. The sea-otter haunts sea-washed rocks, lives mostly in the water, and approximates to the seal in its habits. Its fur is generally employed for collars, cuffs, and trimmings. It is very beautiful, of a deep velvety maroon brown, the anterior parts being of a silvery grey. A fine skin of the sea-otter is worth about £40, and a muff of this skin costs about twenty-five guineas.

2. PLANTIGRADÆ.

This group includes the family of the *Ursidæ*, or bears—heavy, stout-bodied animals, with thick limbs and a very stout tail—which inhabit the wooded and mountain districts of the arctic, temperate, and sub-temperate regions of the northern hemisphere. The commonest bear-skin in the English fur-market is that of the

Black Bear (*Ursus Americanus*), which is imported into this country generally from British North America, and chiefly for military accoutrements. It is made into caps, rugs, pistol holsters, etc. In 1864 we imported 13,311 black bear skins, valued at £21,047.

* A *regular* pentagon is one which has all its sides and angles equal.

The skins of the polar bear (*Thalassarctos maritimus*), the brown bear (*Ursus arctos*), and the grisly bear (*Ursus ferox*), are also imported by us in small quantities.

The *Raccoon* (*Procyon Lotor*) is indigenous to North America, and usually frequents the sea-shore and the margins of rivers and swamps, where it lives upon small animals, birds, insects, and mollusca, with the addition of roots and succulent vegetables.

In 1864, 639,657 skins of the raccoon, valued at £74,538, were imported into the United Kingdom. Two-thirds of this number were re-exported, principally to Germany, where they are used for making hats. The hair of the upper part and sides of the body is of uniform length and colour, and is employed for the linings of coats, for rugs, etc.

The *Badger* (*Meles vulgaris*, Desmarest) is found throughout the northern parts of Europe, Asia, and America. Its habits are nocturnal, inoffensive, and slothful. Its feet are plantigrade, and its long claws enable it to dig with effect, and burrow in the woods. It feeds on roots, earth-nuts, fruits, insects, frogs, and the eggs of birds. Its muscular strength is great, and its bite proverbially powerful. The American badger (*M. Labradoricus*) is larger than the European species. About 5,000 skins are annually sent over to this country by the Hudson's Bay Company. The long hairs are employed for making shaving brushes and painters' pencils. In Europe, badgers are hunted with dogs; in America, they are caught in early spring, whilst the ground is frozen, by pouring water into their holes.

The *Glutton*, or *Wolverine* (*Gulo luscus*), inhabits the northern parts of the American continent. Wolverines feed chiefly upon the carcases of beasts which have been killed by accident. They are very troublesome to the Hudson's Bay trappers, for they will follow the marten hunters' path round a line of traps extending from forty to sixty miles, and render the whole unserviceable, by removing the baits, which are generally the heads of partridges or bits of dried venison. They resemble the bear in their gait, and feed well; they are generally, when caught, found to be very fat. The fur is a fine deep chestnut colour, with a dark disc on the back. About 1,000 skins are annually received in this country. The fur of the wolverine is much esteemed in Germany and Russia, and used for cloak linings, muffs, and sleigh robes.

3. PINNIGRADÆ.

This group includes the family *Phocidæ* (Latin *phoca*, a seal), and comprises the seals, sea-bears, and walruses, which are found chiefly in the arctic and antarctic seas, and are of great value alike for their oil, bones, and skins. The chief hunting-grounds are the fields of pack ice in the Greenland seas, and around the shores of Spitzbergen.

The Saddleback or Harp Seal (*Calocephalus Grœnlandicus*).—This species, which is the most important of the *Phocidæ* in commerce, is at all times gregarious, but never seen to assemble in such numbers as during the months of March and April, when it takes to the ice to bring forth its young. During those months a pack of ice three miles in diameter has been calculated to have no fewer than four millions of seals upon it. Its length does not exceed eight feet. The name *saddleback* is given to it from an aggregation of black well-defined spots scattered over a yellowish-white ground in the form of a saddle or harp.

For the capture of this seal, especially during the breeding season, many ships are annually sent out, and the number taken yearly amounts to hundreds of thousands. The success of the sealers varies; for a ship one year may obtain as many as 20,000 seals, and next year not capture a hundred. The chief art of sealing lies in finding out where the main body of seals is located; a sort of instinct directs these animals in flocks of hundreds to a common centre, where they remain in one great group till the young are capable of taking to the water.

This species is highly prized. From its blubber the Greenlander and Esquimaux procure light and heat; they cover their boats and bodies with its skin, make thongs with its entrails, a *derg* or float with its stomach, and ingeniously fashion the teeth into tips for their arrows and harpoons.

The *Bladder-nose Seal* (*Stemmatopus cristatus*) inhabits, as the last, the Greenland seas, and is found in small groups of

three or four. On account of the beauty of its fur, and the immense amount of its blubber, it is much sought after. It differs from the other species in having a thick black—in the young, delicate brown—woolly coat, which lies beneath its outside bristly hair.

The *Common Seal* (*Phoca vitulina*, L.) is found on the coasts of Scotland, France, and other parts of Europe. . The usual haunt of this species is a hollow or cavern in a rock near the sea, and above high-water mark. They are extremely watchful, seldom sleep more than a minute, raise their heads, and, if nothing is to be seen or heard, lie down again; but if disturbed, they instantly tumble off the rocks into the sea. They are usually shot when asleep. If surprised by the hunter at a distance from the shore, they hasten to the water, flinging stones and dirt behind as they scramble along, and expressing their fears by piteous moans. When overtaken, they make a vigorous defence with their feet and teeth until killed.

We imported from Greenland, British North America, and the United States, as well as from Norway, Russia, and other parts of Europe, in 1867, 743,511 undressed seal-skins, valued at £174,998.

The skin of the seal, when tanned, is employed in the making of shoes; and when dressed by the furrier, serves for the covering of trunks, and for articles of clothing, such as caps and hats, mantles and muffs, coats and boots.

RODENTIA.

The *Rodentia* (Latin, *rodo*, I gnaw), or gnawing mammalia, are, for the most part, of small size, but numerous and prolific. They are distributed all over the world, even in Australia, which possesses some few indigenous species. They have two pairs of curved cutting or incisor teeth, which project from the front of each jaw, and from two to six molars on each side, but they are devoid of canine teeth. The rodents of the greatest value in the fur market are—

The Beaver (*Castor fiber*, L.).—This animal is found in Canada, where it frequents the banks of rivers and marshes, making large dams with the stems of trees plastered with mud to keep out the water, and building rude dwellings in the water, with considerable engineering skill and ingenuity. The fur of the beaver consists of two kinds of hair, one long and rigid, forming the outer coat, the other soft and downy; it is the latter which is employed for coat linings, muffs, and other articles of dress. About 80,000 beaver-skins are annually sent over to this country from North America by the Hudson's Bay Company.

The Musk Rat, or Musquash (*Fiber zibethicus*).—This animal is a native of Canada. It is much smaller than the beaver, which it resembles in its fur and habits, and with which it associates. Above a million are annually taken by the Canadian trappers, and their skins sent over to the fur markets of this country; dressed in the same way as beaver-skin, they form a cheap and durable fur for ladies' wear.

The *Nutria*, or *Coypu Rat* (*Myopotamus Coypus*), inhabits South America, living near streams, and burrowing in their banks. It is smaller than the beaver, and also differs in the possession of a round, hairy tail. Its skin forms a good substitute for that of the beaver, and is dressed in a similar manner. In some years one million nutria-skins have been imported from South America into the United Kingdom.

The Squirrel (*Sciurus vulgaris*, L.).—Light, nimble, and graceful animals, living on the branches of trees, feeding on nuts and other hard fruits, which they gnaw through with their sharp front teeth, carefully removing every particle of skin from the kernel before eating it. Squirrels are distributed through all parts of the world except Australia, but are especially abundant in North America. Their skins are used entirely for ladies' and children's wear, and are sent in enormous numbers to our fur markets under the name of *calabar*. About 2,000,000 are annually imported. The fur is sometimes dyed to imitate sable. The tail is used in the manufacture of boas and artists' pencils. Besides the common squirrel, *Sciurus cinereus* (the grey squirrel), *S. niger* (the black), *S. Caroliniensis* and *S. Hudsonius* (the American red squirrel), yield useful and ornamental furs.

The Chinchilla (*Chinchilla lanigera*).—An elegant, active little animal, inhabiting the Andes of South America, in Chili and Peru, and living at a considerable altitude. The posterior legs are longer than the anterior, and the animal when feeding sits upon its haunches, holding its food between its short fore-paws. The ears are very large and broad. The fur, which is very thick, soft, and of a greyish colour, reaches us through the South American markets. Chinchilla fur is greatly admired for winter clothing, and is made into muffs, mantles, boas, cloak linings, trimmings, and other articles for ladies' and children's wear.

The Hare (*Lepus timidus*) *and Rabbit* (*Lepus cuniculus*).—The skin of the rabbit, when dressed and dyed, is made into all sorts of cheap and warm winter clothing; that of the hare is frequently worn over the chest as a protection against external cold. We have large supplies of rabbit-skins sent to our markets from the rabbit warrens of Norfolk, the Orkney and Shetland Islands, and Ostend. Upwards of 1,000,000 rabbits are sold yearly in London, and more than a quarter of a million of hare-skins are annually imported into this country from Russia, Germany, Denmark, Friesland, Poland, Wallachia, Turkey, Greece, and Sicily. The best and the greatest number come from Russia.

RUMINANTIA.

The animals of this order are distinguished from the other mammalia by the remarkable facilities which they possess for ruminating, or chewing their food twice over. In the majority the lower jaw alone is furnished with incisor teeth, their place in the upper jaw being occupied by the hardened gum. The molars are separated from the incisors by a considerable gap in the jaw. Examples: sheep and deer.

The American Buffalo, or Bison (*Bison Americanus*, L.).—Vast herds of buffaloes roam over the western prairies of North America, and hundreds of thousands of them are annually killed. Buffalo robes are much esteemed in America as sleigh coverings; about 70,000 are annually made up and sold in New York. During the Crimean war our soldiers found these robes of great service; about 20,000 buffalo robes were furnished by the English Government amongst other army supplies.

CHEMISTRY APPLIED TO THE ARTS.—II.

BY GEORGE GLADSTONE, F.C.S.

DYEING.

THE art of dyeing was discovered at a very early period of human history, and is practised by nearly all races of men; nevertheless, it has greatly profited by the advance of science, and even within the present generation it has been the subject of very great improvements. Many of the colours now regarded with most favour were altogether unknown to our fathers, while others have been rendered more permanent, and most have been cheapened in cost.

The materials used in dyeing are derived from very various sources, and their number is legion. There is, indeed, scarcely any limit to the variety that might be employed, and in an article like the present we can only pretend to name a few of those which are most commonly used by dyers. They form two distinct classes, which must be constantly borne in mind, in order to arrive at a clear comprehension of the dyeing process:—(1) The colouring matters; (2) The mordants and alterants

1. The great majority of the colouring matters in use are derived from the vegetable kingdom, though some of the others are of the very greatest importance. Of these it may suffice to name alkanet root, aloes, annatto, orchella and other lichens, barberry root, barwood, Brazil wood, camwood, logwood, Saunders' wood, yellow berries, indigo, madder root, quercitron, safflower, turmeric, woad, and weld. The animal kingdom supplies the cochineal and kermes, which, as well as lac, an exudation produced by an insect, furnish very beautiful varieties of red. The metals arsenic, chromium, copper, iron, etc. in the form of salts, all produce valuable colours, though the compounds of arsenic are very deleterious both to the dyer and to the wearer of clothes so dyed, and should certainly be discouraged. There are also some artificial products which have been successfully prepared by modern chemists, and which bid fair to revolutionise the art of dyeing; thus, what are called the aniline compounds have furnished some of the most favourite dyes of the last few years; and alizarine, a still more recent

production, will probably soon dispense to a great extent with the use of madder roots, the bulkiness of which considerably enhances the cost of bringing them from abroad.

2. The most important mordants and alterants are the alums, the salts of iron and tin, and a variety of vegetable substances which contain tannin. Of these last the principal are catechu, fustic, sumach, gall-nuts, dividivi, valonia, myrobalans, etc. Some of them exercise a double function, and might be included amongst the list of colouring matters, but their chief value brings them more appropriately under the second category.

The operation of the first class needs little explanation, but that of the latter lies at the very root of the art. It will readily be understood that a highly coloured liquid may be obtained by boiling down or steeping certain substances in water, and that if a piece of calico be immersed in the solution, it will take up a certain amount of the colour; but it follows almost as a necessary consequence that a dye so produced can be washed out again with almost equal readiness. If this were all, dyeing would be of no value. The importance of mordants consists in their so fixing the colours that they shall not wash out or otherwise lose their depth or brilliance; and that of alterants in their bringing out or changing the tint produced by the dye stuff. By means of the latter a much greater variety of shades is obtained, and even some colours which can scarcely be derived at all from a mere combination of dyes.

Some very interesting chemical reactions take place in the use of the dyes mentioned under the first head, which must be noted, as they are highly instructive. By far the most important in the list of vegetable substances is indigo. It is commonly known in this country as a lump of purplish stuff, having a bloom upon it like a ripe plum. In the dye vat, however, it presents a very different appearance. Indigo, in the state in which it is imported, is actually insoluble in water, and most other solvents will not even touch it; but by expelling the oxygen which it has absorbed in the course of preparation, it returns to its original condition of white indigo, which is soluble in an alkaline liquid. The blue indigo of commerce is therefore ground up with water till it forms a thin paste, then put into a vat of water and stirred up with sulphate of iron (copperas) and lime, in the proportion of 1 lb. of indigo to 2 lb. of sulphate of iron and 3 lb. of lime; the result is that the sulphuric acid leaves the iron and combines with an equal quantity of the lime, the oxygen of the blue indigo takes the place of the sulphuric acid which has left the iron, forming an oxide of iron, and the excess of lime which remains in the water renders the indigo soluble. The indigo having parted with its oxygen is no longer blue, but has returned to its original colourless condition. When the sulphate of lime and oxide of iron which have been produced in the vat have thoroughly settled to the bottom, the cotton fabric or yarn which has to be dyed is dipped into the liquor, and the fibres become filled with the solution. The goods are then taken out of the vat, hung up, and exposed to the action of the air, when the oxygen out of the atmosphere again enters into combination with the white indigo in the fibre of the cloth, and restores its blue colour. This blue indigo being, as already mentioned, altogether insoluble in water, we have here a permanent colour which cannot be washed out. Wool may be dyed by precisely the same process, except that the liquor in the vat must be maintained at a high temperature, whereas cotton is dyed cold. Other modes of using indigo are employed by some dyers, or for special purposes, in which madder is a principal ingredient, but in every case the result is due to the chemical action above described.

Indigo naturally leads to the consideration of what are commonly known as the aniline dyes, so named from their chemical relation to this substance, *anil* being the name given by the Spaniards to indigo. The terms *mauve*, *magenta*, etc., are now familiar as household words, though it is scarcely eighteen years since the colours represented by them were quite new to the public. Aniline itself, which was originally made from indigo, had been produced from coal-tar by two or three different processes; until the date above referred to, however, the substance had not attracted any very special attention, and its compounds were not known to produce the colours now so familiar. This discovery was due to Mr. Perkin, and the demand which suddenly sprung up for the dye soon led to the manufacture of aniline from coal-tar, on a scale never before attempted, and, by subsequent improvements in the process, at a much more moderate price than heretofore. The mode of application of these dyes will have to be considered later on.

Madder is perhaps next in importance to indigo, and possesses some special features of interest, though the processes involved in its use are by no means so simple as those above described. This dye has hitherto been obtained from the roots of the *rubia tinctorum*, a plant which is largely cultivated in the south of Europe and in Asia Minor. Its value consists in its containing a substance called garancine or alizarine. This article will furnish, in combination with various other ingredients, a variety of tints, from yellow to orange, and up to a deep red. Unlike indigo, it requires the presence of a mordant in order to secure a satisfactory result. The one generally used in dyeing with madder is alum. The cloth to be dyed is first steeped in a solution of alum, and being thoroughly impregnated with this article, it is ready for the reception of the dye which may be intended. Let us suppose that an intense red is required; a solution of alizarine with one of the alkalis (such as ammonia or soda) would be used, and into this the cloth, already permeated with the alum, would be introduced. The mordant would take up the alizarine until it was thoroughly saturated with it, the cloth thus acquiring the desired colour; but were the process to be continued beyond this point, the excess of alizarine in the liquor would be liable to further decomposition, producing a new compound, called rubiacin, which would have the effect of rendering the colour more dull; it is therefore important so to regulate the relative proportions that this after effect may not take place. The madder roots themselves contain but a small per-centage of the colouring matter, the inevitable result of which is that the dye is costly. So important an article is it, however, that, notwithstanding the price, it is very largely used both in this country and on the Continent. Chemists have, in consequence, been led to study the composition of this dye, and their labours have recently been rewarded by discovering a means of producing artificial alizarine which shall fulfil all the reactions of the natural product. The history of this achievement is one of the deepest interest to the experimental philosopher, as well as to those who are likely to profit by it in a commercial point of view. It would take up too much space to describe all the steps by which the result was finally attained; suffice it to say that from a study of the chemical formula (consisting of definite proportions of carbon, hydrogen, and oxygen ($C_{14}H_8O_4$), it was believed to bear a certain relation to other substances which are produced artificially. This view was confirmed by converting some of the alizarine taken from the madder roots into anthracene ($C_{14}H_{10}$), which is obtained by the distillation of coal tar. This having been proved, it only needed a means of reversing the operation, which has since been discovered—alizarine, absolutely identical in all its properties with the dye obtained from the madder roots, having been made from anthracene. A second source of supply of an article quite indispensable to the dyer is thus provided by the mineral kingdom.

Chromium, in the form of bichromate of potash, is a metal which is very extensively used, especially in the formation of yellows, orange, and reds. In dyeing cottons the process depends upon a chemical reaction, the fabric being first immersed in a solution of one of the salts of lead, so as to supply a base which possesses a greater affinity for the chromium than potash does. Thus, if the goods be impregnated with nitrate of lead, and subsequently with bichromate of potash, the chromium will leave the potash and combine with the lead, forming chromate of lead, which produces a yellow dye. Again, should an orange colour be required, the process can be carried a step further; the article so dyed yellow would then be boiled in a bath of lime-water, during which operation the lime will take up a portion of the chromium, leaving a subchromate of lead behind, which produces a rich orange. Some persons use acetate of lead in preference to the nitrate, but the principle involved in either case is the same. Chrome is also employed in dyeing woollen goods with various colours, in combination with many of the vegetable dyes; in these operations alum is almost always used as a mordant, and the solution into which the

article to be dyed is dipped must be maintained at the boiling-point.

The use of a mordant has incidentally been mentioned in treating of madder and the chromates of potash. Its proper function is to fix the dye, so that it shall not wash out again. Alum, as we have seen, has this property; a fabric which has previously been dipped into a solution of alum being able, not only to take up a much larger quantity of some colouring matters than it would otherwise, but also to retain them so persistently that the colour becomes fast. In some cases the mordant and the dye are applied separately, while in others the two are mixed, forming a coloured liquor in which the article to be dyed is steeped, and so far reducing the number of operations. It appears probable that the action of such a mordant as alum is to enter into actual combination with the substance of the thread or cloth, and not merely to fill the capillary tubes with a substance insoluble in water, as in the case of cotton dyed with indigo; hence, in consequence of the greater affinity of alum for animal substances than for other materials, the effect of this mordant is much more decided when applied to wool and silk than to cotton and flax.

Various salts of iron exercise, in a pre-eminent degree, the double function of mordant and alterant. Sulphate of iron, or copperas, is, for instance, used as such in dyeing cotton blue with ferrocyanide of potassium or the red prussiate of potash, while the nitrate or sesquichloride of iron, combined with the ferrocyanide or yellow prussiate of potash, will produce the same result; the chemical action in either case is the same—the acid leaves the iron and combines with the potash, while the cyanogen completes the exchange by uniting with the iron, thus forming a compound cyanide of iron, commonly known as prussian blue. Here we have an illustration of the effect of an alterant, the resulting colour having no relation to that of the ingredients which are brought into combination, but being due to chemical action only.

Of all the metals, however, tin is the most important as a mordant, the various oxides of tin having a very powerful affinity both for vegetable colouring matters and for the materials which are to be dyed. The effect of these salts (or spirits, as they are called by the dyers) is to produce very permanent colours. The salts generally used in the dye-house are the chlorides; the oxides being insoluble except in the presence of an acid, or in combination with an alkali, such as soda, in which case the tin itself acts the part of an acid, forming stannate of soda.

A great variety of vegetable substances, all containing tannin in more or less quantity, are used in dyeing, which act both as mordants and alterants. The tannic and gallic acids which they furnish exercise a very powerful chemical action upon some of the other materials employed, especially the metallic salts. With sulphate of iron, for instance, these acids produce a deep black, of which the common writing-ink furnishes a familiar example.

To give a description in detail of all the various processes for dyeing different kinds of goods, and of the several combinations which are best adapted to produce the almost endless varieties of tint, would fill a goodly volume. In the next article some of the most important general directions will be given, and one or two of the principal colours will be treated at length, as an illustration of the nature of the dyer's art.

AGRICULTURAL DRAINAGE AND IRRIGATION.—II.

By Prof. Wrightson, Royal Agricultural College, Cirencester.

WATER-LOGGED SOIL—ADVANTAGES OF LAND DRAINAGE.

The beneficial action of land drainage may at first sight appear somewhat paradoxical. That the partial removal of water, the want of which is often so keenly felt, which may be beneficially poured over growing crops in quantities far exceeding the natural rainfall, and which not unfrequently composes ninety per cent. of the actual weight of fresh vegetables—that the removal of this most essential constituent of plants from the soil should be attended with good effects certainly appears puzzling, and demands our careful attention. It will, then, be our first object to explain why the drainage of land is beneficial; and, secondly, we shall point out the nature of those practical good effects which have rendered the art popular.

Let us consider the condition of a soil surcharged with moisture, and compare it with one in which, from natural or artificial means, the superfluous water finds egress.

The fact that the land is wet is sufficient proof that some obstacle exists preventing the escape of water. The subsoil may be sufficiently impervious to prevent the downward passage of water to lower strata, or there may be a source of water in the form of springs too plentiful to allow of its sufficiently rapid removal by natural drainage. From either or both of these reasons the land is "water-logged," by which we mean that all the interstices of the soil that would otherwise be filled with air are occupied by water. This water is in a stationary condition. If it is not, it will move in the line of least resistance, and the soil will be more or less perfectly drained. Having, however, assumed that the soil is wet, we must conclude that its condition is the effect of the water not being able to escape.

(1.) What, then, are the consequences of this stagnant condition? In the first place, air is excluded. Now the effect of air upon the soil is most beneficial, and without it it is impossible for any plant to develop. The first consequence of an insufficient supply of oxygen is the formation in the soil of organic and inorganic substances of a decidedly deleterious character. Vegetable matters remain in a state of partial or imperfect decomposition. Such a condition is unfavourable to plant life; and its evils are the more apparent when we remember that with a sufficient supply of oxygen such compounds would not only be removed from an actively hurtful state, but would become a source of carbonic acid and ammonia (the products of perfect combustion), and thus directly nourish growing crops. Lower oxides and sulphides of iron are also the result of decaying vegetable matter in the soil, which, in its condition of arrested decay, removes the oxygen previously associated with iron, thereby reducing the peroxide to the condition of protoxide. The removal of superfluous water at once admits air, and with it oxygen, and by this means the soil is brought into a "sweeter" and more wholesome condition.

(2.) Water, when it exists in a stationary or stagnant condition in a soil, fails to exert those beneficial influences that constitute its peculiar value. Rain-water contains traces of carbonic acid, as well as of other valuable substances. This carbonic acid exerts a solvent action upon the mineral matter in the soil, gradually changing it from an insoluble and unavailable condition into one in which it can be assimilated by the roots of plants. It is only, therefore, in drained or naturally dry soils that the valuable qualities of rain can be thoroughly realised.

(3.) Not only is rain comparatively valueless to wet soils, but there is a danger of its becoming actively injurious. Not being able to sink into the already occupied soil, it washes the surface, and, as it trickles into the water-furrows and ditches, carries with it the finest particles of earth, as well as manurial substances that have been applied as fertilisers. This is, however, not the worst evil consequent upon defective drainage. The top layer of soil becomes surcharged with moisture, and this can only be got rid of by evaporation. The larger the surface, and the more completely it is exposed to the air, the greater will be the evaporation. In the case of drained soils, the water is quickly removed from the effect of drying winds, and evaporation is proportionally checked. In wet soils, on the contrary, the conversion of water into vapour is the cause of a greatly diminished temperature.

It has been calculated that the heat given off from the combustion of 1 lb. of charcoal is required to evaporate 12½ lb. of water, and when we remember that the rainfall upon an acre of land is equal to something like 6,000,000 lb., it will be readily seen that, where a large proportion of this is to be evaporated, much of the sun's heat, which would otherwise be warming the ground, will be taken up.

(4.) Another reason for the wonderful improvement of land by drainage is the altered texture of the soil. So long as land is constantly wet, its condition, although unfavourable to plant life, is in some respects constant. It is not subjected to the modifying influences of contraction and expansion to so great an extent as drained soils. A drained field is alternately, and

within a very short period, dry and wet; it is also acted upon by the atmosphere, and that weathering action which, in the long course of time, has broken down and pulverised rocks, and so formed soils, is promoted, so that further pulverisation and a finer mechanical condition of the soil is the result. The alternate contraction and expansion also causes the formation of a deeper layer of available soil, and renders lighter the work of cultivation. As water rises from the deeper layers of the soil to the surface, it brings with it the saline substances it has taken up in solution. These are carried by capillary action to the surface, where, as the water is evaporated, they are left in the form of an incrustation, which to a great extent prevents the entrance of air into the soil. This phenomenon is frequently noticed in the case of flower-pots watered by means of a saucer. In this case the water, as it evaporates from the upper surface of the soil, leaves a white efflorescence which, from the cause already referred to, is prejudicial to the plant, and requires to be frequently broken up in order to admit air. The same phenomenon has been observed in the case of agricultural soils.

Having traced the causes of the beneficial action of land drainage, let us now glance at those many practical advantages which appeal to the common sense of the landowner, the farmer, and the public. That drained land grows a better crop than undrained land is easily accounted for when we remember the improved chemical and mechanical state of the soil. As every reason we have given points in the direction of an improved condition of soil, it need not surprise us that one quarter (eight bushels) of wheat has often been estimated as the average increase that may be expected after drainage. Instances are not wanting where land has been brought from a worthless into a valuable condition simply by draining it, but the above given measure of the benefit is applicable to soils which, although requiring drainage, were previously useful agricultural soils.

An earlier harvest is a palpable advantage from drainage, and can be explained by the general improvement of the land, and the higher temperature of the soil consequent upon diminished evaporation. Mr. Parkes, the eminent drainage engineer, found, from the mean of thirty-five observations, that a drained peaty soil at seven inches in depth was 10° Fahrenheit warmer than a similar undrained soil at the same depth. This, it will be seen on inspection of any table of temperatures throughout the year, is equivalent to the difference between the climates of February and May. The result of this improvement is harvest a fortnight earlier, and an improved quality as well as quantity of produce. The same causes operate in increasing the number of species of plants which the farmer can cultivate. Thus we find the *bare fallow* disappearing, and root and forage crops occupying the ground. Sheep stock also can be maintained, whereas previously they could not have been profitably kept. Every tillage operation is easier and more effectively performed, and, owing to the water being quickly carried away, the actual number of working days is increased. Thus either a smaller number of horses will be required, or those that are kept will be more equally worked and less expensively fed.

Manures are much more effective upon drained soils; hence this operation is now looked upon as the foundation of good husbandry, and the best farmers consider that it should precede every other improvement.

Grass land derives great benefit from drainage. It sooner assumes a beautiful green colour in the spring; it is firmer under the foot; rushes, sedges, and other water-loving and inferior herbage disappear, and are replaced by nutritious grasses.

The health of the live stock is unquestionably improved, and land drainage is followed by the disappearance of "black-quarter," or inflammatory fever, which in unfavourable situations is a cause of annual loss. The health of the human population is also improved.

Before leaving this most interesting part of the subject, we would recall the attention of our readers to the fact that drainage owes its efficacy to the alteration in the condition of the water in the soil rather than to its withdrawal. If we remove water, it is only because it has accomplished its work, and we facilitate its exit to make room for a new supply. Thus the drainer's art consists, as has been well remarked, not only in getting the water out of the land, but also in getting water *into* the land, and thoroughly using its valuable properties.

We propose, upon a future occasion, after considering the cost of drainage, to select a few instances showing the extent to which land has been improved by the operation; but at present we must pass on to another important point in the theory of drainage—namely, the action of drains in removing water from the land.

THE WATER ECONOMY OF SOILS.

Soils are wet from three causes:—(1) The direct fall of rain; (2) springs; and (3) moisture which finds its way from higher porous strata on to lower ground in a diffused condition.

How far these three sources of wetness are the cause of injury in any given case depends upon the structure of the soil and subsoil. Clay soils, with retentive subsoils, are liable to be wet from the first cause, and they may receive an additional supply from the percolation of water from higher grounds. In soils of a light character resting upon a tenacious clay (a combination not unfrequently met with), the natural rainfall may also be the direct cause of wetness. Springs are met with when a porous soil is underlaid by a clay bed. The rain sinks at once through the upper stratum until it is arrested by the impervious bed beneath. There it accumulates and rises until it either wets the surface or, following the line of least resistance, bursts out at a lower level in the form of a spring. Springs are very commonly seen upon the sides of hills.

Fig. 1.

The accompanying diagram (Fig. 1) shows the conditions under which springs often occur. A represents a porous stratum; B represents a clay bed which obstructs the downward passage of water; C D represents the level to which water will require to rise before it overflows in the form of a spring at D. In dry weather, when the "reservoir" or "water-table" sinks below the line C D, the spring will be dry; but on the return of wet weather it will again become active. These facts exert an important influence upon the practice of drainage.

The drainage of *porous* soils is exceedingly simple. All they require is an outfall for their superabundant water. They are wet simply because the water they receive direct from the clouds, or from higher levels, cannot escape; and when egress is given to this superfluous moisture, they at once take their place among naturally dry or drained soils. With clay soils the case is somewhat different. Not only must an outfall be given, but the whole bulk of the soil between the drains must be thoroughly aërated before their drainage is complete. Such soils hold the water which incommodes them with a tight grasp, and a much more close and complete system of underground channels, supplemented by steam or other deep cultivation, is necessary before the same effect is produced as in the case of lighter soils. Thus, in light, porous soils the distance between the drains is sometimes as great as sixty yards, while in clay soils they are often placed only six yards apart.

In order to understand the action of drains, it is necessary to bear in mind that in all wet soils there exists, at a greater or less distance from the surface, a something which prevents the escape of water; that the effect of continued rain, or an accession of water from other causes, tends to accumulate water upon this obstruction, thereby forming a "water-table" or level of supersaturation; and lastly, that above this supercharged level the soil is wet by capillary attraction, which lifts the water to a greater or less height according to its texture and condition. Before land can be thoroughly drained it is essential, not only to lower the "water-table," but to so lower it that capillarity shall not so saturate the superimposed stratum as to render it injurious to growing vegetables.

In our next paper we hope to still further elucidate this portion of our subject, and to point out the important action of capillary attraction in the water economy of soils.

BUILDING CONSTRUCTION.—III.

FOUNDATIONS UNDER WATER.

In our previous lessons on this subject we have insisted on the necessity that exists for procuring a good foundation for buildings of all kinds, and have explained the methods of effecting this by the employment of concrete and piles in soft soil of any description. We now pass to the mode of making foundations under water.

Foundations under water are constructed in various ways. The most ancient, and certainly the most simple, is that called by the French "pierre perdue" (or lost stones). This method consists in shooting rough stones, etc., into the water, and leaving them to settle themselves as they happen to fall. When the heap rises to the surface, it is levelled, and the superstructure raised upon it. This system has been used principally for the erection of piers and breakwaters, but is not adapted for structures of a permanent character, as light-houses, being erected upon it, as the external portions are liable to be washed away, and therefore the mound requires frequent repair. Nor do the stones always fall exactly within the prescribed area, but may reach a greater distance than was intended. The system is, therefore, not adapted for river works, where any narrowing of the water-way for vessels is of consequence.

A breakwater is a barrier intended for the protection of shipping in harbours or anchorages, by *breaking* the force of the *waters* as the mighty waves roll towards the shore. Sometimes a small island is situated opposite a bay, and thus forms a *natural* breakwater. This is in some degree the case with the Isle of Wight, which occupies such a position as to protect Portsmouth and Southampton.

The Plymouth breakwater (Fig. 1), built by John Rennie,* is the best known of these constructions. The Sound, or harbour, being open to the south, was so much exposed to storms, that early in the present century it was determined to erect a breakwater across it, with openings on either side between it and the shore to allow of the passage of vessels. The works were commenced in 1812, by transporting along a tramroad large blocks of limestone from a neighbouring quarry. These were then carried by vessels fitted with trap-doors, and were thus deposited on the required spot. The good effect of the mound was felt as soon as it began to rise above the surface, but the great storm in November, 1824, threw a large quantity of the stones over into the Sound, and it was not until 1841 that the works were finally completed by the deposition of more than 3,000,000 tons of stone, and the expenditure of £1,300,000. The breakwater is nearly a mile long. The central portion is 1,000 yards, and two wings, of 330 yards each, extend from the ends of this at a slight angle. The open channels at each end, between the breakwater and the shore, are each about half a mile wide, and their depth is respectively 40 feet and 22 feet at low water. The breakwater is 133 yards wide at the base, and 15 yards at the top, the two sides being made very sloping for the security of the stones; the slopes and top are faced with masonry. The water-space or area forming Plymouth Sound, which is protected by this breakwater, comprises 1,120 acres.

There are breakwaters at Holyhead, Portland, and Dover, but the limits of the present lessons preclude descriptions of them. The above description of the Plymouth breakwater will therefore serve as an illustration of the system of "pierre perdue" or "random" foundation. In some cases blocks of *bêton* have been used with success.

Foundations under water are sometimes laid in *coffer-dams*. This is done by driving parallel rows of piling around the site on which the pier is to be built; these piles are kept in their places by horizontal timbers, so as to form a coffer or strong box around the site. The space between the parallel rows of piling is filled with clay, puddle, etc., well rammed down, so as to render the wall thus formed water-tight; this is one of the principal difficulties in the system, whilst another presents itself in the pressure of the water on the outside, which is resisted by struts placed inside the coffer-dam, extending from side to side. When the coffer-dam takes the form of a wall, and is intended to keep out the water during the building of a wharf, quay, etc., the struts are placed obliquely, and act as buttresses.

When the structure is deemed satisfactory, the water is pumped out of the enclosed space, the bottom of which is then excavated and levelled until a solid stratum be reached, or, if there be any difficulty in doing this, a bed of concrete or *bêton* is laid down.

If solid ground is not found within available depth, the plan adopted is to drive piles a few feet apart all over the area. These are then surrounded by sheet-piling, to prevent the soft soil escaping. Stones, concrete, etc., are then rammed in between the piles; the heads of the piles are cut off at one level; sleepers are laid across and fastened to them, and on these massive planking of great thickness is placed, on which the building is erected.

Before the application of steam power to pumping, this system was very expensive, and another was introduced into this country by a Swiss architect, named Labelye, and was first used in the erection of old Westminster Bridge, which was commenced in 1739.

The method adopted by Labelye (which, however, did not prove a good one) was the using of a *caisson*, or large water-tight chest (the word "caisson" meaning a large box or *caisse*). The bed of the stream was first carefully levelled by dredging. Strong frames of timber were then constructed, having upright sides like those of a box. These were floated over the place where the piers were to be built, and the masonry of each pier was commenced inside the caissons. When the first course was laid and cramped together, water was admitted by sluices into the caisson, which then sank. The bottom was not, however, found to be sufficiently level; the sluices were therefore closed, the water was pumped out of the caisson, and it was floated again. The ground was then again dredged and levelled, and this operation was performed three times before the mass of stone settled on a level bed. The pier was then built on this foundation, after which the sides of the caisson were removed and used for the next pier. Blackfriars Bridge, erected in 1760, was also built by caissons. In both these cases, however, the foundations proved failures, and both of the bridges have been removed, and that at Westminster is replaced by the elegant structure designed by Mr. Page, completed in 1862; and the new Blackfriars Bridge was, it will be remembered, opened by Her Majesty in person on the 6th of November, 1869.

Hitherto we have spoken of wooden piles, and before proceeding to mention those formed of iron, which are now so much used, it is deemed advisable to give the student some little information concerning piles and pile-driving. The piles, then, are squared beams of timber pointed at the bottom. The timber used for this purpose is oak, beech, fir, and larch. The piles are bound at the top by strong iron hoops, in order to prevent their being split by the force of the blows which drive them down; they are also protected at the bottom by iron shoes. When the piles are to be placed singly, the point is pyramidical, that is, cut to a *square* point (Fig. 2); but for sheet-piling the ends are cut *flat* (Fig. 3), so as to present an *edge*

* John Rennie was born at Phantassie, in East Lothian, in 1761. His early education was obtained in the parish school of East Linton, and he subsequently learned mathematics at Dunbar. He was for some time a workman in the employ of Mr. Andrew Meikle, an ingenious Scotch mechanic, who in 1787 invented the threshing machine. After attending various lectures on Natural Philosophy and Chemistry, he was taken into the employ of Messrs. Boulton and Watt, near Birmingham, and soon displayed such mechanical genius that Watt, in 1789, entrusted him with the direction of the construction and fitting up of the Albion Mills, London. His improvements in millwork were so striking that he at once rose into general notice as an engineer of great promise, and the thorough efficiency of his workmanship greatly contributed to his fame. To this branch of engineering he added, in 1799, another—the construction of bridges; and, amongst numerous others, he built Waterloo and Southwark bridges over the Thames, the latter built of cast-iron arch girders resting on stone piers. He also drew up the plans for London Bridge, which was not, however, commenced until after his death. In addition to numerous bridges, the London Docks, the East and West India Docks at Blackwall, with their goods sheds, the Hull Docks, the Prince's Docks, Liverpool, and those of Dublin, were all designed and wholly or partially executed under his superintendence. Besides the Plymouth Breakwater, Rennie planned many improvements in harbours and dockyards in Portsmouth, Chatham, and Sheerness. He died in October, 1821, and was buried in St. Paul's Cathedral.

rather than a point, and this edge, too, is a little slanting, that is, the triangular face is a little longer at one side than the other. (This has already been referred to in lessons in "Technical Drawing," but is here repeated in order to render the instruction as clear as possible.) The purpose of this is, that as the pile is being driven down, it will have the tendency *towards* the last pile which has been driven, and so a closer wall of piles will be formed. When sheet-piling is constructed, one pile is placed at each end of the required width, and a few others at intervals. These are called *guide* piles, and to these horizontal timbers are attached, called *wales*, which guide the rest of the piles, so that they may be placed in a straight line.

Piles are forced into the ground by pile-drivers or engines. The subject of these lessons precludes any lengthened description of such machines; it will be sufficient to say that a pile-driver consists of vertical guide-bars, between which a weight called the "monkey" is drawn up, either by a number of men or by steam power, and is suddenly released, when its weight descends like a huge hammer on the head of the pile, which in this way is driven into the soil. Nasmyth's steam pile-driver consists of a guide-bar, with the required machinery for hoisting the hammer, etc. This hammer is an important application of Nasmyth's steam-hammer. The "monkey" is attached to the piston-rod, working, as in the steam-hammer, *downwards* from the cylinders; it acts in an iron guide-bar, resting on the top of the pile which is being driven, the steam being led from the boiler to the cylinder by jointed pipes, which allow of the motion as the pipe sinks. Another important pile-driver, which was first used in the construction of St. Katherine's Docks, London, is the atmospheric engine, which is worked by an air-pump and a steam-engine.

Fig. 1.

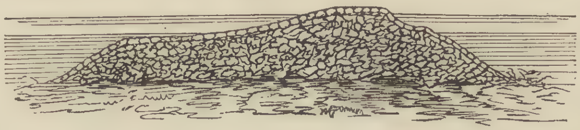


Fig. 3.

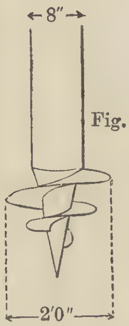


Fig. 4.

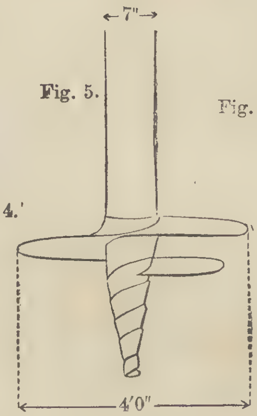


Fig. 5.

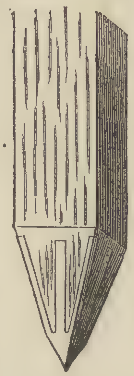


Fig. 2.

We shall have an opportunity of entering at greater length into the construction of these important engines in another series of lessons, and at the same time give some illustrations of them. When piles have only been used for a temporary purpose they are either cut off at the level of the ground or are drawn up; the latter plan, however, must always be adopted with great care, lest the vacuum caused by the withdrawal of them should weaken the foundation. Piles of cast iron were first employed in the construction of Bridlington harbour. The piles used in this work were formed of plates of iron, so contrived at the sides that each pile was united by a dove-tailed joint with the adjoining one. In 1822 Mr. Ewart took out a patent for iron piling, and the success of those employed by him emboldened others; eventually cylindrical iron piles were introduced, and are now largely employed.

These vary, according to the nature of the work, from three to seven feet in diameter. They are first lowered into the water, and driven as far as they will go without great difficulty into the ground; a quantity of clay is then placed around the outside of them, for the purpose of preventing the water forcing its way underneath the bottom. The water is pumped from the inside, and the workmen then descend into the cylinder and dig away the soil, which they send up in buckets, thus literally undermining the cylinder, which then sinks either by its own weight or by additional pressure. The pile is formed of parts, and at the top of the first part are flanges, which also exist at *both* ends of the other section. As one part sinks, another is bolted on to it, until the required depth is reached. On the ends of these cylinders the platform of girders and planking is constructed.

The screw-piles, introduced by Mr. Mitchell, are admirably adapted for loose, movable, and even sandy soils, and have been found very useful in situations where all other means have failed.

These piles are of wrought iron and are hollow, and terminate at their lower end in screws of various shapes (see Figs. 4 and 5). They are screwed down into the bed of the river or the bottom of the sea until the pile is firmly fixed; their heads are then connected by sleepers, and the superstructure raised upon the base thus formed. The lighthouse on the Chapman Sand, in the mouth of the Thames, is built on such piles seven inches in diameter and about forty feet long; the blade of the screw, which is of cast iron, is four feet in diameter. They are screwed down to the depth of about thirty-seven feet; on their heads iron girders, braces, etc., are bolted; and on these the lighthouse, which is entirely of wrought iron, is erected. The piles are seven in number, one driven in the centre, and the others at equal distances around it.

The plan which was adopted by Mr. Page, C.E., for getting in the piles of the new bridge designed by him at Westminster, described by Mr. Ashpital, is so novel and important that no course of lessons could be deemed complete without a slight description of it.

Rows of strong elm piles, about thirty feet long, are driven into the bed of the river, passing first through the gravel, which is about four or five feet thick, and then going about twenty feet into the London clay. There are about 140 or 150 piles to each pier, ranged alternately in threes and fives; around these a range of cast-iron piles is driven, about four feet apart. These are round, fifteen inches in diameter, and have strong grooves cast on each side of them; they, however, go into the clay only ten or twelve feet. Into these grooves large plates of iron, which the engineer calls "plate piles," are fitted, and driven down between the piles; they go about ten feet into the blue clay, and extend about a foot or two above the natural bed of gravel. Upon these is a series of slabs of granite, placed edgewise, retained in their places in the following manner:—

The bottom rests on the plate-piles, the edges are secured to the round iron piles, and the tops to the other masonry; the plate-piles are secured together by two sets of ranges of iron rods, passing through the pier and tying them together; these are all fixed by the divers. It will be seen, therefore, a sort of case or box is made, which surrounds the wooden piles on all sides; the loose standing mud is then dredged out, and the case filled up solid with hydraulic concrete, in which, of course, the piles are embedded, and the whole forms one solid mass to about a foot above low-water mark. At this level the tops of the piles are cut off, and on each top a stone, 2 feet square, and $1\frac{1}{2}$ feet thick, is bedded, the spaces between which are again filled in with concrete. The gravel is then dredged out around the pier on the outside of the case, and the space also filled with concrete. It has been urged that the steamers would come into collision with the round piles, and break them so that the granite slabs will escape, as it were, and fall into the river. This, however, cannot be as long as the concrete remains in its place, as the top of the slab is secured by the masonry, and the bottom would not be accessible. It is, however, intended to protect the piles by floating booms, which will prevent the chance of collision, and will act as safeguards for the steamers as well as the bridge.

THE STEAM-ENGINE.—I.

By J. M. Wigner, B.A.

PRIME MOVERS — SOURCE OF THE POWER — MECHANICAL EQUIVALENT OF HEAT — PROPERTIES OF STEAM — THE BOILER—WAGON, CORNISH, FLUE, AND TUBULAR BOILERS —SUPERHEATER.

In early times the advance of civilisation rendered the employment of machinery almost a necessity, and the need of some prime mover, other than the power of man, soon began to be felt. The force of the wind, and the power developed in running streams, would be the first to suggest themselves, and were early employed. A great inconvenience, however, attended the use of these agents, as they were uncertain and irregular in their action. A long-continued drought would so far reduce the level of many streams, that any hydraulic contrivances which had been set in motion by them would stand idle and useless, however much they might be needed. The uncertainty of the wind was also proverbially great, and a calm might occur just at the time when the machinery was required to act. The power of animals was, of course, in these cases, turned to account; but here again inconvenience and difficulty were experienced. The animals had to be fed and tended whether any work were required or not—thus entailing constant expense. Attention was, therefore, very naturally turned to the discovery of some source of power which should be certain and uniform in its action, well under control, and, withal, economical in its employment. The power which has up to the present time most perfectly succeeded in carrying out these various conditions is that of Steam. Many other prime movers — among which may be mentioned Electricity, Heated Air, and Gas—have at various times been suggested, and tried with varying degrees of success. None of them have as yet exceeded, or even equalled, the force of Steam; but it is the opinion of many who are best competent to form a judgment on such a subject, that some of these will ultimately take the place that steam now occupies, and that the steam-engine will thus become among the things of the past. Be this as it may, the undoubted fact is that in the present day steam is all but universally adopted as the moving power in all our factories, large and small; and there is scarcely any article that we employ in our daily life, but in some stage or stages of its manufacture has been operated upon by its agency.

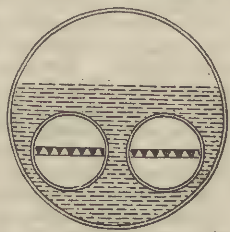


Fig. 2.

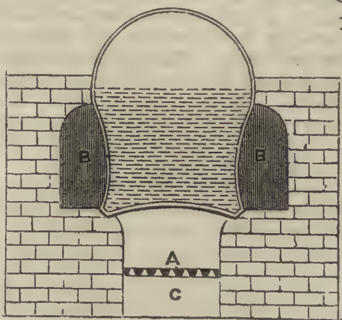


Fig. 1.

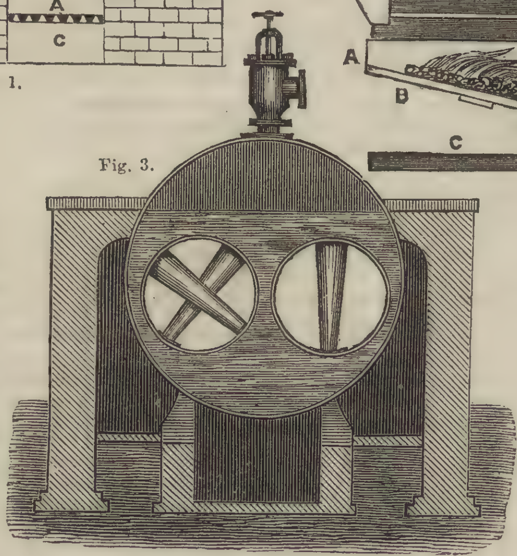


Fig. 3.

Even before the Christian era the attempt was made by Hero, the well-known philosopher of Alexandria, to drive an engine by the power of steam issuing from two small apertures, much in the same way as the hydraulic machine, known as Barker's Mill, is set in motion by the reaction of the water as it issues from openings in the two arms.

A scientific toy, acting on precisely the same principle, was a short time since brought out by the London Stereoscopic Company, under the title of "The Little Marvel" steam-engine, and was sold in large numbers.

It would be very interesting and instructive to trace the gradual development of the steam-engine from this, its earliest germ, down to the present time, but this would be foreign to the scope of the present papers, which is to furnish a practical description of its construction and action. We must, however, pay a passing tribute to James Watt, to whom more is due than to any other of the almost numberless engineers who have made or suggested improvements. In fact, we may say that, in most of its essential features, the steam-engine of the present day is the same as completed and perfected by Watt.

We must first inquire into the actual source of the power produced by the steam-engine; for it must be carefully remembered that no machine can *create* force—all that it can do is to control or modify its action. The source of the power, then, must be sought for in the fuel consumed in the furnace. As was explained in our lessons on Heat in The Popular Educator, heat and force are to a certain extent mutually convertible.

Illustrations of the conversion of force into heat are familiar to almost every one. We have a practical exemplification of it every time we strike a lucifer match, and, by the friction, generate sufficient heat to ignite the inflammable compound with which it is tipped. We are not, however, so familiar with the fact that heat may be converted into mechanical force. Such, however, is the case; and as the result of a long series of experiments, very carefully conducted by Dr. Joule and others, we learn that the amount of heat required to raise 1 lb. of water 1° Fahr., is sufficient to exert a mechanical force equal to raising a weight of 770 pounds to a height of one foot.

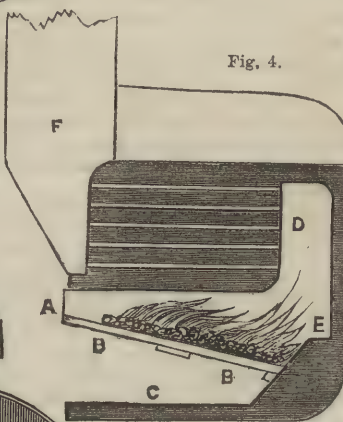


Fig. 4.

Every pound of coal or other combustible consumed in a furnace is capable of performing a certain definite amount of work, and the steam-engine may therefore be defined as "a machine in which the motive power of heat is utilised and made to accomplish any desired work." The problem to be solved is to discover in what manner the largest portion of this heat may be rendered available, and most of the improvements made in its construction have this as their aim.

At present, however, we cannot consider this problem as by any means satisfactorily disposed of, for, even in our best constructed machines, the actual work accomplished is seldom, if ever, more than one-eighth of the theoretical amount, and in the large majority of cases it falls considerably below even this. This subject is, of course, one which demands and has obtained much attention from practical men. One great cause of the waste appears to be that the extremes of temperature in the boiler and condenser are not sufficiently removed from one another. The greater this interval, the greater is the power obtained; in the engine, however, it is seldom above 200°; for although the temperature in parts of the furnace is frequently 3,000°, that of the steam is seldom much above 300° or 350°, there being practical difficulties in the way of employing it at a higher temperature.

If we take a vessel of water, and apply heat to it, the tem-

perature will gradually rise till it reaches 212°. At this point, if the vessel be an open one, it becomes stationary, and bubbles of invisible vapour, or steam, are formed at the surface exposed to the source of heat. These rise through the liquid, causing ebullition, and then escape into the air, where they soon become partially condensed, and are thus rendered visible. If the water be contained in a close vessel, the pressure of the steam generated gradually increases, until at last, if no escape be provided, it bursts the vessel.

By allowing the steam to enter an empty vessel, we find that it occupies a very large space as compared with the water from which it is produced, the increase in bulk being rather more than 1,700 times. As an easy mode of remembering this, we may state it thus:—A cubic inch of water, when converted into steam at the ordinary pressure of the atmosphere (15 lb. per square inch), occupies the space of a cubic foot. If the pressure be increased, the volume will be diminished in a corresponding degree; thus the steam produced from a cubic inch of water will only occupy half a cubic foot when at a pressure of two atmospheres. On removing this pressure, it will at once expand. We see, then, that dry steam—that is, steam when above the point at which it is condensed—possesses the properties of an elastic gas, and it is to these properties, and to its great increase in bulk compared with that of the water from which it is generated, that we owe its employment in the engine. It may be well here, as a caution, just to remind the student that true steam is an invisible gas. That which we see issuing from the funnel of an engine or the spout of a kettle, is in reality partially condensed steam, that is, minutely divided particles of water suspended in the air.

We must not imagine that it is sufficient merely to raise the water in the boiler to a temperature of 212°, and that then it will at once be converted into steam. Were this the case, no vessel would be strong enough to withstand the sudden pressure thus produced, for the water would, on attaining the boiling-point, explode with a violence almost equal to that of gunpowder. The real fact is, that a large amount of heat is absorbed in the conversion of water into steam. If we take any vessel containing water at a temperature of 32°—that is, just at the freezing-point—and having placed a thermometer in it, expose it to a uniform source of heat, we can easily ascertain the exact time it requires to attain the boiling-point. Now let the heat continue uniform, the water will slowly boil away and be converted into steam, and we shall find that about five and a-half times as long is required to evaporate all the water as was taken to raise it from the freezing to the boiling point. The temperature of the steam has, however, at no time exceeded 212°; it is clear, therefore, that this additional quantity of heat has all been stored up or rendered latent in the steam.

This may easily be proved. If we close the vessel, and allow the steam to pass along a pipe into another vessel filled with ice-cold water, we shall find that it has sufficient heat in it to raise five and a-half times its own weight of water to the boiling-point.

Having in this way just explained the more important properties of steam, so far as they relate to the engine, we must proceed practically to explain the mechanism and action of the different varieties of engine generally employed. To do this, the simplest plan will be first of all to explain in detail the construction of some one form, which may, to a certain extent, be regarded as a typical form, and then to trace the various deviations from this, which are rendered necessary by the different requirements of each particular case. The engine which we shall select for this detailed description is that technically known as a Double-acting, Condensing, Beam Engine; the meaning of these terms has been explained in the papers on this subject which have already appeared in THE POPULAR EDUCATOR, and will shortly become more apparent.

From what has been said, it is clear that the first requisite is a vessel in which the water may be contained for conversion into steam. This is technically known as the boiler, and must of necessity be so made as to be water-tight, and of sufficient strength to resist the outward pressure of the steam. It must, further, have such a form, that heat may be easily and economically applied to it. The construction of the furnace is thus intimately connected with that of the boiler, and, as we shall see, the utmost variety exists in the forms given to the two. The object sought is the means of generating the largest amount of steam with the smallest expenditure of fuel; economy of space is also in many cases an important requisite, and hence the form given to the boiler depends partly upon the special exigencies of the case. There are three main classes of boilers, viz., land, marine, and locomotive boilers. The two first-named are stationary, being usually firmly fixed in the position they are intended permanently to occupy. Space is usually more valuable in marine boilers, and hence special arrangements have to be made, even at the expense of an increased expenditure of fuel in proportion to the work accomplished. At the present time, however, the construction of land boilers is, in many respects, becoming more closely assimilated to that of those intended for marine use.

The form known as the "wagon" boiler, and represented in Fig. 1, was introduced by Watt, and for a long time was regarded as a standard form. It has, however, gradually been falling into disuse. Perhaps that most generally employed in the present day is the "Cornish" boiler, a section of which is shown in Fig. 2.

It consists of a cylindrical shell, usually made with flat ends, and has one or two large internal circular flues, in which the furnaces are placed; the hot air, having passed along these, returns by flues made in the surrounding brickwork at the sides or bottom. The cylindrical form is much better calculated to resist the strong internal pressure to which boilers are subjected. In other forms strong internal stays are nearly always introduced, to impart additional strength. The internal flues are firmly riveted to the ends, and materially add to the strength of the boiler.

There are some objections to this form, the main ones being that the space for the furnaces is rather limited, and a sufficient slope cannot well be given to the bars. The tubes, too, unless carefully strengthened, will sometimes collapse from the pressure; but these difficulties may be overcome, and the boiler is reckoned one of the best for ordinary circumstances.

The plan of allowing the flame and heated gases from the furnace to play outside tubes containing the water, instead of passing through tubes filled with it, has been adopted in many instances with beneficial results. An application of this principle has been patented by Messrs. Galloway, and been considerably employed. Conical tubes are made to pass right through the central flues, beyond the combustion-chamber and the fire-bridge, on the plan shown in Fig. 3, which represents an ordinary Cornish boiler with these tubes, which are known as "Galloway Tubes," fitted to it. Owing to their conical form, the flange at the lower end will pass through the opening in the upper side of the flue, and thus save much trouble in the fixing. They are found to serve as a support to the flues, rendering them much less liable to collapse, and at the same time they afford increased and very effective heating surface, and improve the circulation of the water in the boiler. This latter is found to be a very important point. When two furnaces exist, they are usually fired alternately, and in this way the production of smoke is found to be considerably lessened.

The boilers employed for the earlier marine engines were of the class known as flue boilers, and they attained a high degree of efficiency. In these the flues were wholly internal, so that they were surrounded on all sides by a thin layer of water, and the products of combustion were thus made to circulate through the boiler before escaping into the chimney. As will easily be understood, the great object required to be obtained is to absorb as much as possible of the heat, without rendering the draught too feeble. When the heated air escapes into the chimney at a very high temperature, there is, of course, a corresponding waste of heat; the object, therefore, in having these long flues is to enable the water in the boilers to take up as much heat as possible. It will easily be seen that when the flues are internal, that portion of heat which is usually absorbed by the brickwork, and which is by no means inconsiderable in quantity, is saved.

A tubular boiler is, however, now nearly always employed in marine engines. In this the heated products from the furnace, instead of passing along one large flue, are broken up into a number of small streams, which pass through a series of tubes, and thus give up nearly all their heat to the water. In this way it is found that a great economy of space is effected, the heat being much more rapidly abstracted from these small streams. Sometimes multi-tubular boilers are constructed on a

plan very similar to the Cornish boiler already figured. The front part of the flue is fitted with a sloping grate, and serves as a combustion-chamber, which extends only part of the length of the boiler; at the back of this is placed the fire-bridge, against which the flames first impinge. The rest of the flue is replaced by a series of small tubes about two and a-half inches internal diameter. These are, of course, firmly fixed into a tube-plate at each end, so as to render the joints water-tight. A packing of wood is often introduced for this purpose.

Care must be taken not to place the tubes so close together as to impede the circulation of water, as it has sometimes been found that the additional heating surface thus attained is more than counterbalanced by the impaired circulation; in these cases an increased production of steam has been caused by removing a few of the tubes.

With a boiler of this form a return flue is usually unnecessary, and the smoke is allowed to pass directly into the chimney; much of the cost and labour of setting in brickwork is therefore dispensed with.

Another form of boiler, now very frequently employed in steam-vessels, is represented in Fig. 4. In this the furnace passes from end to end of the boilers, and the tubes are placed above it, so that the smoke passes back again along the boiler before escaping into the chimney. A is the furnace-door, B B the fire-bars, which slope away from the front, so that the fuel gradually passes along to the further end, as fresh is supplied in front. In this way the smoke produced, when the furnace is coaled, has to pass over the surface of the highly incandescent fuel at the further end before it reaches the flues, and thus it is to a considerable extent consumed. The gases then strike against the fire-bridge, E, and pass into the space D. From this they travel along the horizontal tubes till they escape into the flue, F. In this way there is but little waste of heat: even the ash-pit, C, is, as will be seen by the figure, within the boiler, so that the heat from it is not wasted.

The tubes in this boiler are, it will be observed, entirely surrounded by water. Sometimes another set is placed above these, so as to be in the steam space, and these serve to raise the temperature of the steam, and thus render it more perfectly dry. This second set is technically known as the "superheater."

Steam in most of its properties resembles a gas, and, like any gas, expands on the application of heat to it. If, then, the steam be exposed to a higher temperature, either its volume or its pressure will be increased, and a greater mechanical effect may therefore be obtained from it. Another advantage is also obtained by superheating the steam. Under ordinary circumstances, when the steam is not at a very high temperature, it is partly condensed by contact with the cylinder and other working parts; and hence there is a deposit of water in them, and a corresponding loss of power. By superheating the steam this is guarded against. A few years ago the tendency was to superheat the steam as much as possible. It is found, however, that if its temperature be raised above 315°, the packing of the stuffing-boxes is liable to become charred, and the oil or other lubricant used in the engine to be injured. The practice, therefore, seems to be gradually diminishing, and is not usually carried much beyond the degree that is requisite to render the steam thoroughly dry.

Very many different forms of superheater have been proposed, and tried with varying degrees of success. The usual plan is to cause the steam to pass through a series of tubes placed at the lower part of the chimney, so that the heat employed is that which would otherwise escape with the smoke. It is not found that when fresh fuel has to be employed, any advantage is gained by employing it in superheating the steam, instead of applying it to the boiler in the ordinary manner.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

III.—ROBERT STEVENSON, ENGINEER.

BY JAMES GRANT.

ROBERT STEVENSON, the creator of the modern lighthouse system in Scotland, the great engineer by whose skill and courage that wonderful structure on the Bell Rock was erected, was born on the 8th of June, 1772, in the city of Glasgow, where his father, Allan Stevenson, was a merchant connected with St. Christopher's. By the death of that parent, when on a visit there, Robert Stevenson was left fatherless at an early age, amid many pecuniary difficulties, on the care of his mother, Jane Lillie, who, with the ambition so usual with the Scottish matrons of the middle and humbler classes, designed her boy for the Church; but, ere his fifteenth year, she had contracted a second marriage with Mr. Thomas Smith, a tinsmith of Edinburgh, a man whose mind was far in advance of his station, and whose studies were devoted to the construction of lighthouses and beacons—a department of engineering in which he had the merit of substituting for the open coal fire and grates previously used, lamps fed with oil and furnished with parabolic reflectors.

This matrimonial alliance caused a change in the prospects of young Stevenson, who threw aside his Latin, Greek, and Hebrew, and devoted all his energies to the views and plans of his stepfather, by whom, so early as his nineteenth year, he was entrusted with the erection of a lighthouse on one of the Cumbrae Isles in the Firth of Clyde—a commission ordered by the Trustees of the River Navigation; and, pleased with the skill he evinced, Smith soon after took him as a partner in his business. In 1799 he married a daughter of Mr. Smith, whom he succeeded as Superintendent of Scottish Lighthouses, an office which he resigned as lately as 1843. During the progress of the work at the Cumbrae, he attended the lectures of the Andersonian University of Glasgow, and mastered the mathematical and mechanical sciences necessary for success in his new profession; in this having the good fortune to obtain for a preceptor, Dr. Anderson, the founder of the institution. His next work was the erection of a lighthouse on the dangerous Pentland Skerries in Orkney, and the close of every summer's work found him studying hard at the University of Edinburgh, where he rapidly passed through a curriculum that included mathematics, natural and moral philosophy, chemistry, natural history, logic, and agriculture. He was a striking example of the hard, resolute, and persevering Scottish student, and ere long he became a most accomplished and scientific scholar. He made his first tour of inspection as Superintendent of Lighthouses in 1797, and during his term of office he erected no less than twenty-three of these edifices in the far Northern Isles, many of them being constructed in perilous situations, the difficulties of which, by land and water, could alone be overcome by the most anxious thought, courage, and scientific care.

In 1824 he published an account of the most durable monument of his high attainments and success—the erection of the lighthouse on the Bell Rock, a dangerous and sunken reef of red sandstone, near the mouth of the Firth of Tay, in west longitude from Greenwich 2° 22′, and in north latitude 56° 29′. In ancient times it was named the Inch Cape, and thereon in the Middle Ages an abbot of St. Mary's of Arbroath hung a bell, which was rung by the waves and wind, as a warning to seamen; and this bell is said to have been spitefully destroyed by a famous rover, named Sir Ralph, whose ship perished on the fatal reef a year and a day thereafter. So much for Southey's ballad and old Scottish tradition; but every winter saw many vessels cast away there, and among others, in the great storm of December, 1799, H.M.S. *York*, of 74 guns, when running for the Forth, foundered thereon, and every man on board perished. The wreck alone survived to tell their story.

This catastrophe made the outcry for a lighthouse general, and that on the Eddystone was proposed as a model. But the obstacles to be overcome in this instance were greater than in those of the former, which occupies a reef barely covered by the tide at flow, while the Bell Rock was barely uncovered at its lowest ebb. The Trinity House at Leith (a humane endowment of Mary of Guise, Queen Regent of Scotland) had erected no less than three great beacons on the rock; but these the sea swept away in rapid succession. In the summer of 1800 it was visited by Robert Stevenson, who had modelled a pillar-formed lighthouse for the place, even before the loss of the *York;* but he saw that it would prove unsuitable, though he deemed it quite practicable to erect a solid stone tower on the Eddystone plan, and his drawings for this purpose, with estimates for the expense, amounting to £42,685 8s., were submitted to the Lighthouse Board, and at once accepted.

He procured a Prussian vessel of 82 tons—a prize taken during the war—as a habitation for his workmen, which he

named the *Smeaton*, in honour of the constructor of the Eddystone lighthouse, and prior to mooring her off the reef, he rounded both her stem and stern that she might ride more easily. She was rigged with three masts, each surmounted by a copper lantern, while another vessel of 40 tons conveyed the stones from Aberdeen, where they were hewn in the granite quarries of Rubislaw, and also from Mylnefield, near Dundee. On the 12th of August, 1807, the foundation-stone was laid, and soon "such was the clink of hammers, the hurrying of feet, and the din of human voices, which now invaded the solitude, that the affrighted seals, who had hitherto regarded the Bell Rock as their own exclusive property, went off in shoals in quest of new settlements."

The erection was a seven years' task, beset by hourly difficulties, and an incessant struggle with the shifting elements. On one occasion the *Smeaton* broke from her moorings and was drifted into the German Sea, leaving Robert Stevenson with thirty-two workmen on the desolate rock, which by the flowing tide would soon be submerged to the depth of twelve feet, while the two boats they had would not have carried off more than half their number. It was a perilous and terrible situation. Who were to go, and who were to be left to drown? Stevenson was not without hope that the drifting *Smeaton* might poik up the boats if she came to leeward; accordingly, he was on the point of haranguing his terrified men on the perils that menaced them, and urging them to be of good courage and put their trust in God. His idea was, that all should strip and cast away their clothes as an unnecessary incumbrance and additional weight, and that a specified number should cling to the gunwales in the water, while others rowed them all towards the shore. But when he attempted to speak, his tongue was so parched by excitement and the saline atmosphere, that speech failed him; however, at that critical juncture, there was a cry of "A boat! a boat!" and through the mist one was seen approaching. It proved to be the pilot craft with letters for the workmen, and all quitted the Bell Rock that evening, happy at escaping a too probable death; but all were drenched to the neck by the surf.

During the first season the *Smeaton* floating-light was Stevenson's abode while the work progressed; many a hard gale he rode out in the old Prussian hulk, and many a night the adventurous engineer endured all the horrors that precede a shipwreck—of being blown adrift on the one hand, or dashed on the rock itself, as a sudden and final catastrophe, on the other. After a time he got a kind of "pigeon-house," as he names it, built of logs, exposed, however, to the assault of every wave. In fine weather the breakers rolled sixteen feet high against it, while in gales the spray rose ninety feet above the sea-level.

At four o'clock one evening, as Stevenson records, "the water broke into the cook's berth, when he rang the alarm-bell, and turned up all hands to attend to their personal safety. The floor was completely burst up by the force of the sea, while the whole of the deals and articles remaining on the floor were swept away, such as the cast-iron mortar tubs, the iron hearth of the forge; the smith's bellows and even his anvil were thrown down on the rock. Before the tide rose to its full height to-day, some of the artificers passed along the bridge into the lighthouse to observe the effect of the sea upon it, and they reported that they felt a slightly tremulous *motion* in the building when the great waves struck it in a certain direction about high-water mark. It was quite impossible for me to do anything for their relief, until the gale should pass off."

Amid such obstacles and enduring toils, the Bell Rock lighthouse was completed in December, 1810, and since then, far over the wild German Sea, night after night, its lamps have shone as a guiding-star; while in the haze and snow, its great bell is heard to clang as in the days of the humane abbot of St. Mary's, amid the dense atmosphere, a warning to seamen, and the means of saving many a human life. In July, 1814, it was visited by Sir Walter Scott, whose "Diary" records the pleasure and novelty he experienced on that occasion; and when there he wrote in the album some lines which Stevenson adopted as the motto for the title-page of the history of the undertaking.

Stevenson next contemplated a lighthouse on the Skerry Vhor, in the Isle of Tiree, one of the Hebrides, a design afterwards carried out successfully by his son Allan, also a talented engineer, in 1842.

Robert Stevenson always acknowledged that the Eddystone lighthouse suggested to him the more difficult erection on the sunken Bell Rock, while his plans of the jib and balance-cranes, and the changes he adopted in the masonry of the tower, in laying the floors so that the stones of each should form a portion of the *outer wall*—thus binding the whole mass together—were improvements on the plans of Smeaton, whom he was ever proud to call "his master." The lamps were also an invention of Stevenson's, being intermittent and flashing; the former disappearing at irregular intervals, and the latter emitting a powerful gleam every five seconds. For this he received no reward from his own country, or native sovereign, but the King of the Netherlands presented him with a gold medal.

Ultimately, he made the system of the Scottish lighthouses so perfect, as to be a model to other maritime nations. He was a frequent co-operator with Rennie, Telford, and other great engineers of the time; and after the peace of 1815, he was the principal adviser in the construction of all those new harbours, bridges, roads, canals, and railways, towards the formation of which Scottish energy and capital became suddenly directed; and the new and beautiful approach to Edinburgh from the east, by the Calton Hill and Regent Bridge, was cut through the rocks under his immediate direction. He suggested the new form of suspension bridge applicable to small spans, avoiding tall piers; and this form was partially adopted in the bridge over the Thames at Hammersmith.

For a timber bridge at Meikle Ferry he designed an arch of a new construction. It was composed of thin layers of planking bent into circular form, and stiffened by ring-post-pieces, on which the level roadway rested, and this form is now in general use in the construction of railway bridges.

He was author of many articles in the "Encyclopædia Britannica," in Sir David Brewster's "Edinburgh Encyclopædia," and the old "Scot's Magazine," etc.; his professional contributions making altogether four good-sized quarto volumes. In 1815 he was made a Member of the Royal Society of Edinburgh, of the Geological Society of London, and of the Wernerian and Antiquarian Societies of Scotland.

In private life he was universally esteemed as intelligent, kind, amiable, and benevolent, and he died universally regretted in his seventy-ninth year, at Baxter's Place, Edinburgh, on the 12th of July, 1850. A bust of him was subsequently executed by Samuel Josephs, and, oddly enough, placed by the Commissioners of the Northern Lighthouses—where few indeed will care to visit it—in the library of the tower on the Bell Rock.

PROJECTION.—V.

TO PROJECT A PENTAGONAL PRISM.

LET A B C D E (Fig. 61) be the plan, and $e \, {}^{d}_{c} \, a$, $e' \, {}^{d'}_{c'} \, a'$ (Fig. 62) the elevation when one of the long faces, A B, is at right angles to the vertical plane. Fig. 63 is the elevation, looking directly at the point E. The mode of obtaining this elevation has been shown in Fig. 40. The upper end of the axis is shown at g in the centre of the plan,* and its position in the elevation is at $f\,g$. Now it will be remembered that the ends of a right prism are equal and similar planes, parallel to each other,† these ends being united by lines at right angles to their surfaces; and it will therefore be evident, that projecting a prism is only repeating the process of projecting a plane. Thus let it be required to draw the plan of the prism when resting on A B, its axis at 45° to the horizontal, and parallel to the vertical plane. It has already been shown that the axis is parallel to the edges of a prism; consequently, as the axis is at 60°, so will be the edges. Therefore, place the line $a\,a$ (Fig. 64) at 45°, and on this line construct the elevation of Fig. 61; project the ends (Fig. 65) by dropping perpendiculars from the points in the elevation (Fig. 64), and intersecting these by horizontals from the

* To find the centre of a regular polygon:—Bisect two of the angles of sides which adjoin each other, and the point where the bisecting lines meet will be the centre.

† When the planes forming the ends of the prism are at right angles to the long sides (that is, so that if the prism stands on one of the ends, the long sides may be vertical), it is called "a right prism." When the planes of the ends are slanting to the length of the prism, it is called "oblique." In these lessons all prisms are assumed to be "right," unless otherwise expressed.

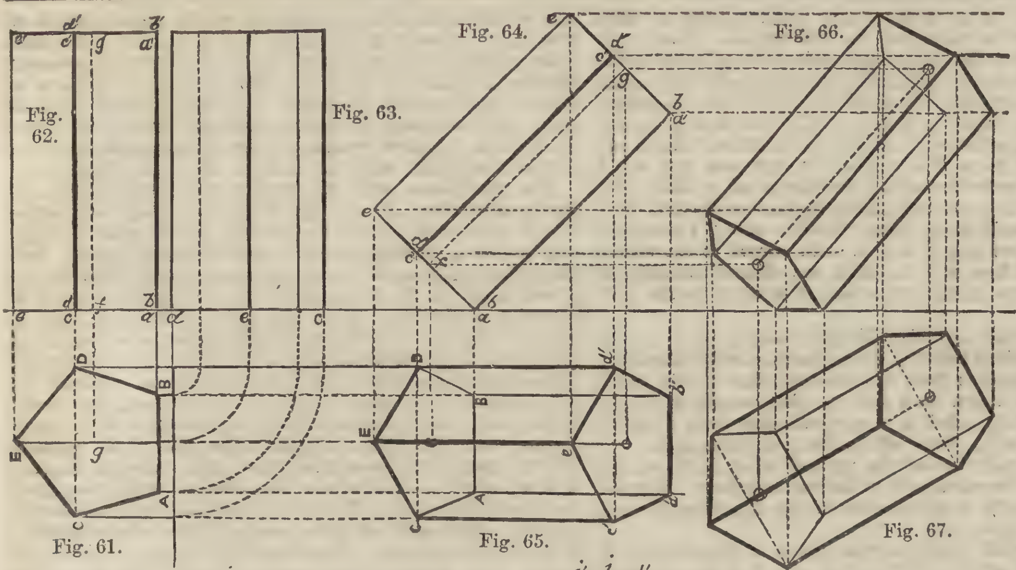


Fig. 61. Fig. 62. Fig. 63. Fig. 64. Fig. 65. Fig. 66. Fig. 67.

corresponding points in the plan of Fig. 61. Unite the points of these two plans by lines representing the long edges of the prism, which will then be seen to be parallel to the vertical plane (Fig. 65).

Fig. 66 shows the prism when the axis is at 45° to the horizontal, and 30° to the vertical plane. In this figure it will only be necessary to place the plan of Fig. 65 at the required angle with the intersecting line, viz., Fig. 67; then perpendiculars drawn from the angles, intersected by horizontals drawn from the corresponding points in the elevation, will give the projection.

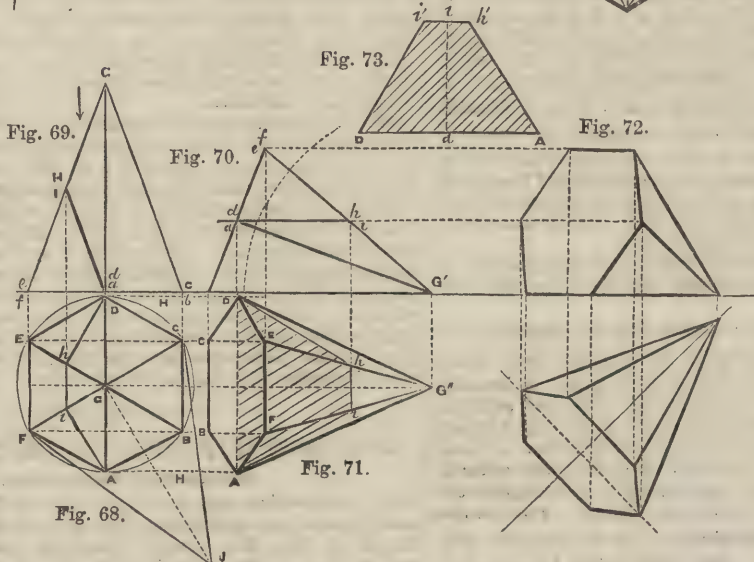


Fig. 68. Fig. 69. Fig. 70. Fig. 71. Fig. 72. Fig. 73.

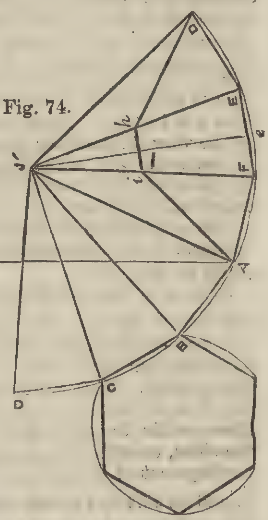


Fig. 74.

OF PYRAMIDS.

A pyramid is a solid which stands on a triangle, square, or polygon, and terminates in a point, all its sides being, therefore, triangles.

The axis of a pyramid is the line joining the centre of the base to its summit, called the apex. When the axis rises from the centre of the base, and is perpendicular to it, the sides will be all equal triangles, and the solid is called a right pyramid. When the axis is not at right angles to the base, the pyramid is called "oblique." When the upper part of a pyramid or cone is cut off, the solid is said to be "truncated."

Fig. 68 is the plan, and Fig. 69 the elevation of a hexagonal

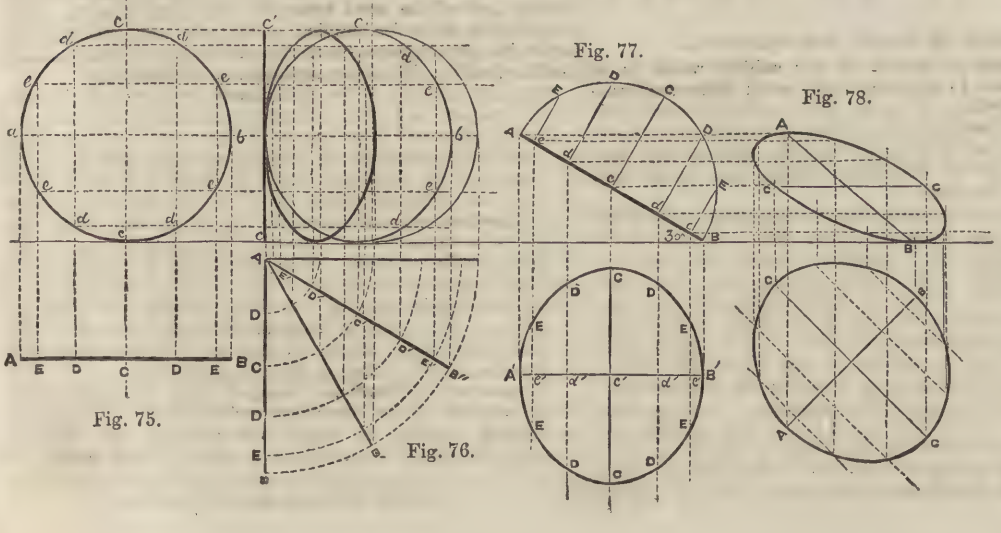


Fig. 75. Fig. 76. Fig. 77. Fig. 78.

pyramid when two sides of the plan, B C and E F, are at right angles to the vertical plane, and its axis vertical. Now let it be required to draw the plan of the pyramid when lying on the side B C G. The elevation (Fig. 70) will be precisely the same as in Fig. 69, altered only in position. It will be self-evident that if a pyramid stood on a plan, and, whilst resting on the line B C, it were gradually turned over until it should lie on one of its triangular faces, the widths F E, B C, and A D would remain the same, notwithstanding the change of position; for, supposing pieces of board were placed upright on the lines H H, the angles A, D would touch these "wooden walls" throughout the movement; but this is not so with regard to the widths from E to C, and from F to B, which are altered according to the position of the plane of the base in relation to the horizontal plane.

The points for the plan (Fig. 71) will therefore be found by producing the straight lines E C, F B in the plan, and intersecting them by perpendiculars from the corresponding points in the elevation. A line drawn from G in the plan parallel to the intersecting line, intersected by a perpendicular from G′ in the elevation, will give G″, which will be the plan of the apex.

Fig. 72 is the projection of the pyramid when lying on one of its faces, with its axis at 45° to the vertical plane. In order to test the student's comprehension of the foregoing lessons, this figure is left unlettered.

It is now required to find the true shape of the section *a d*, H I (Fig. 69). It will be evident that, as *a d* in the elevation represents A D in the plan (Fig. 68), A D will be the width of the section at its base. Therefore, draw A D (Fig. 73), and erect a perpendicular at its centre. Make this perpendicular equal to $\frac{d\ \mathrm{I}}{a\ \mathrm{H}}$, and draw a line through *i* parallel to A D. From $\frac{\mathrm{I}}{\mathrm{H}}$ (Fig. 69) draw a perpendicular cutting the radii F and E of the plan in $\frac{i}{h}$. Join *h i*, *i* A, *h* D. Then A D *i h* will be the plan of the section, or the view of it looking downward in the direction of the arrow. On each side of *i*, in the true section (Fig. 73), set off half the length of the line *i h* in the plan—viz., *i′ h′*. Join *h′* A and *i′* D, which will complete the form of the section.

The next step is to develop the covering of such a solid. It is hoped that, after the instructions already given, this will prove an easy task.

From G in the plan (Fig. 68) draw a line, G J, perpendicular to F C, and equal to the height of the pyramid ($\frac{d}{a}$ G). Draw F J, C J, which represents the section which would be bounded by a diagonal of the base and two of the *edges* (*not sides*) of the pyramid. With J F as radius, describe an arc (Fig. 74), and set off on it the lengths equal to the sides of the base. Join all these points to each other and to J′. On C B, or any other of the sides, construct a regular hexagon, which will complete the development of the pyramid and base. Bisect E F by the line $\frac{\mathrm{J}'}{e}$, and on this line set off the height, *e* I, on the elevation (Fig. 69), and through I draw *i h*. Join these points to each other and to A, D; this will give the section-line marked in the development.

PROJECTION OF CIRCLES AND CYLINDERS.

We now approach a branch of our subject which is of especial importance to engineers and metal plate-workers—namely, the projection of circles and cylinders, and their development. As, however, the previous lessons have gradually led up to this point, it is hoped that the student will have been so prepared for the subsequent studies that he will find but little difficulty in them.

Fig. 75 is the front elevation of a circular plane; and it will be seen that the plan of this is a mere line, A B, equal to the diameter of the circle. (The aperture in a child's money-box is the plan of the penny which drops through it.) To prepare this disc for projection, divide its circumference into any number of equal parts, as *a e*, *e d*, etc., and from the points *a*, *e*, *d*, etc., drop perpendiculars to cut the plan A B in the points similarly lettered. If now we rotate the disc so that its plan is at right angles to the intersecting line (Fig. 76), the elevation, too, will be a line, *c c′*, equal to the diameter. To project this circle, transfer the points C, D, D, and E, E to plan A B (Fig. 76). Let it then be required to find the forms of elevations when the plane of the disc is at 60° and 30° to the vertical plane. Place the plan at each of these angles, as A B′ and A B″. Taking A as a centre, describe arcs from the points in the plan to cut the plans A B′ and A B″ in C′ D′ E′. From each of these points draw perpendiculars, and from the points similarly lettered in the elevation draw horizontals. The intersections of these two sets of lines will give the points *c*, *d*, *e*, etc., through which the curve is to be drawn by hand in the first instance, but it may subsequently be inked by means of the French curve, or centres may be found from which parts of the ellipse may be struck.

The principle on which the projection of a circle is founded having thus been shown, Fig. 77 gives a simplified method. Let it be required to draw the plan of a circle when resting on one end of a diameter which is parallel to the vertical plane, the surface being at 30° to the horizontal plane. The line A B, placed at 30° to the intersecting line, will then represent the elevation of the disc. From the centre of this line, with the radius of the circle it is intended to project, describe a semicircle, and divide it into a number of equal parts, A E, E D, etc. From each of the points A, E, D, etc., draw lines meeting A B at right angles in the points *c*, *d*, *d*, *e*, *e*. Draw any line parallel to the intersecting line, and draw perpendiculars to it from A and B; then this line A′ B′ will be the plan of the diameter which is parallel to the vertical plane. The semicircle drawn on A B represents one-half of the disc lifted up until it is parallel to the vertical plane. The lines C *c*, D *d*, and E *e* thus show the distance which each of these points in the circumference is from the diameter A B. Therefore, from *e*, *e*, *c*, *d*, *d* in the elevation draw perpendiculars passing through the plan of the diameter A′ B′ in *e′*, *d′*, *c′*, *d′*, *e*. From these points set off on the lines drawn through them, and on each side of A′ B, the lengths *e′* E, *d′* D, *c′* C, etc., and through the points thus obtained the plan is to be drawn.

Fig. 78 shows the mode of projecting a circle when its surface is at 30° to the horizontal, and one of its diameters at 45° to the vertical plane. Place A B at 45° to the intersecting line, and on it construct the plan by measurement from Fig. 77. This is best done by drawing a line, C C, at right angles to the diameter, A B, and on each side of the intersection marking off the distances *e*, *e*, *d*, *d*. By drawing lines through these points at right angles to A B, and making them the same length as in the plan of Fig. 77, the points for the present figure will be obtained. From these points in the plan draw perpendiculars, and from the points correspondingly lettered in the elevation of Fig. 77 draw horizontals, and the intersections will give the points through which the projection of the circle is to be drawn.

MINERAL COMMERCIAL PRODUCTS.—V.

CALCAREOUS* SUBSTANCES.

THE metal *calcium* very readily oxidises and forms lime, which easily enters into combination with carbonic acid, forming carbonate of lime (the base of limestone, chalk, marble, and calc-spar), and with sulphuric acid and water to form gypsum. Carbonate of lime in its various forms is a most abundant substance, and of the most extensive use, whether in its native condition as stone for building, paving, statuary, and smelting, or in its preparations—mortars and cements, in glass-making, leather-dressing, bleaching, agriculture, and medicine.

Common limestone is found in almost every geological formation; compact and often crystalline in the older rocks, but generally loose and more earthy in the newer. It is abundant in nearly all countries, in varying qualities and degrees of adaptation to its numerous uses. In England it chiefly occurs in the rocks of the Devonian and Carboniferous series—mountain limestone especially—and in the Liassic and Oolitic systems. The dolomite or magnesian limestone belongs to the Permian group of rocks. The best kinds of limestones for building are those of Portland, Bath, Box, and Corsham, all of which are Oolitic, and the magnesian limestone of Notts and Yorkshire. The oolite of Bavaria furnishes a very fine lithographic stone; these stones are also supplied from older rocks in Canada, and from France, Greece, and Portugal.

Of ornamental limestones, those of South Devon are extensively worked. Some interesting varieties of the red, grey, and variegated marbles (so called) are obtained near Torquay. Many blocks are almost entirely formed of fossil corals, and

* That is, having the nature of limestone.

known as *madrepore* marbles. The Carboniferous rocks of Derbyshire are rich in ornamental limestones, the chief varieties of which are the *entrochal* or *encrinital* marble, *productal* marble, and *black* marble. The former of the first two is built up of the stony fragments of stone-lilies (*Encrinites*), whilst the latter is composed almost entirely of shells of the genus *Producta*. Other marbles of a like character are obtained in Staffordshire, Somersetshire, and Ireland. The Purbeck and Petworth marbles are limestones charged with the fossil shell *Paludina*, and hence are sometimes called paludinal marbles; they belong to the Purbeck and Wealden series respectively, and were formerly used extensively in ecclesiastical architecture.

The true marbles are altered limestones or dolomites. The finest is the pure white or statuary marble; others are red or yellow in colour, and either pure or streaked. They are firm in texture, finely grained, and susceptible of a beautiful polish; hence their use for ornamental purposes. Italy is pre-eminently a marble-producing country, and has of late years produced an average of 250,000 tons per annum of statuary marble. The best white marble is now obtained from Carrara, quarried in the Apennines where they approach the Mediterranean. India, Sicily, Spain, Ireland, the United States, and other countries also furnish it.

Coral limestone belongs to this group of mineral products. It is a recent formation, and the rock is sometimes used as a building stone in the South Sea Islands. Great numbers of these islands, as well as numerous others in the Indian Ocean, are themselves natural coral structures. Coral reefs are abundant in tropical seas and the North Atlantic and Pacific Oceans.

Marl, a mixture of clay with carbonate of lime, occurs as clay-marl, marl-clay, and shell-marl. It is procured from valleys which have formed the beds of lakes, and from the neighbourhood of existing lakes, and is useful as a manure. Calcareous sand, formed chiefly of crushed shells, and found on ancient and modern beaches, is also used in agriculture. Of such sand, 8,000,000 cubic feet are annually removed from the Cornish coast into the interior. The shelly deposits of the Crag formations, in the east of England, are similarly used.

Gypsum is a very valuable mineral, occurring chiefly in the New Red Sandstone and in Tertiary deposits, but also among earlier rocks. It is abundant in England, Ireland, France, Canada, Nova Scotia, and in many other places. Gypsum forms the plaster of Paris, of such utility in building and modelling; crystallised, it is met with in *selenite*, *satin gypsum*, and *alabaster*. The use of this last, for statuary and ornamental work, dates from the remotest times of Etruscan art. Statuary alabaster is obtained from the Miocene and Pliocene strata in Tuscany and in Egypt.

Limes, stuccoes, and cement, so indispensable in all building operations, are obtained from various carbonates. Pure carbonates make rich limes, which are such as set only in dry air; impure ones (with mixtures of clay) yield hydraulic limes, which possess the valuable property of setting in moist air, and even under water. The septaria or calcareous nodules in London clay, at Sheppey, those procured at Harwich, the cement stones of the Lias at Whitby, and of the Speeton Clay of Yorkshire, the Lower Lias Limestone, etc., furnish suitable limestone for hydraulic cements.

SILICIOUS SUBSTANCES.

Another very important mineral substance is silica, which is a combination of oxygen with the metalloid silicium or silicon. The purest examples of silica are rock-crystal, quartz, and flint. The colourless crystals, especially the so-called Brazilian pebble, are much used for lenses. Quartz, which, crystallised, constitutes several of the gems, is an important constituent of granitic rocks; and, in the form of sand, it is the principal ingredient in all sandstones. Quartz, well powdered, is combined with fine clays in the manufacture of porcelain in China, as flint is also in this country. Flints are irregular masses of nearly pure silica, occurring in nodules distributed in layers, in the Chalk formation especially. Reduced to powder, they enter into the composition of china, porcelain, and glass; and, whole, they furnish a rough building material.

Sandstones are of very various composition and of different degrees of hardness. They consist of silicious sands, often mixed with other substances, all cemented together by means of carbonate of lime, oxide of iron, silica, or clay. They are of all geological ages, the oldest being usually the most compact. When hard and coarse-grained they are denominated grits. If pebbles very largely predominate, they are called conglomerates, and these are either pudding stones with rounded pebbles, or breccia with angular fragments. The extremely hard and schistose grits are very useful for flag-paving. The best qualities of these are supplied from Forfarshire and Caithness. Millstones are obtained from the Millstone Grit of Newcastle, from Yorkshire, Belgium, France (especially at La Ferté), and Wurtemburg. They are also made from a silicious limestone near Paris, and out of lava at Andernach. For building purposes, the finest sandstone is quarried at Craigleith and other localities in the Carboniferous formations of Scotland. Good stone is obtained from rocks of the same age in Durham, Yorkshire, Derbyshire, etc., and from Queen's County and other parts of Ireland.

Silicious sands are much in request in the arts, as in building for mortars, in moulding and casting, and in glass-making. The most valuable for the last-named purpose are procured from Senlis in France, from the Isle of Wight, Lynn Regis, Aylesbury, and Reigate. *Rottenstone*, found in Derbyshire and elsewhere, is a decomposed silicious limestone, and is used for polishing. Bath brick, Tripoli powder, the polishing powder from Bilin, in Bohemia, the *Berg-mehl* of Sweden and America, and the French *tellurine*, are peculiar mealy forms of silica.

IGNEOUS AND METAMORPHIC ROCKS.

Granites, and their allied rocks, gneiss, mica-schist, and felstones, consist largely of silica. Their chief mineral constituents are quartz, felspar, and mica (white, green, or black). Felspar is a silicate of alumina and potash, or, in the case of *albite*, the white felspar of Cornish granite, of alumina and soda. Mica is a silicate of lime and alumina or iron. Where hornblende, a dark-green silicate of lime and magnesia, has taken the place of mica, the stone is called *syenite*. These rocks assume a structure termed porphyritic—that is, they are composed of crystals embedded in an amorphous matrix—and are highly valued for ornamental purposes. These latter, and white granite, are obtained from Cornwall and Devon, red and grey granites from Aberdeen and Peterhead, and a very hard and dark variety from Guernsey, the Malvern Hills, and Leicestershire. Granitic rocks are abundant in many parts of the world, Ireland, Norway and Sweden, India, and China among others; and Egypt is famed for its syenite and red porphyritic felstone. They furnish a durable and highly polishable building material, particularly well suited for bridges, quays, and monumental works. The coloured varieties are eminently adapted for ornamental purposes. *Mica* is often found in large crystals, which can be split up into plates and used as glass. This is the material known as Siberian glass, from the country whence it is supplied. *Talc* is a similar mineral, and is employed in the porcelain and crayon manufactures: it forms, besides, the French chalk. *Asbestos* is a fibrous variety of hornblende. It can be woven into a fire-proof cloth, and is also made available in open gas stoves.

PRINCIPLES OF DESIGN.—II.

By Christopher Dresser, Ph.D., F.L.S., etc.

EGYPTIAN ORNAMENT—GREEK ORNAMENT—EARLY CHRISTIAN SYMBOLISM.

In my former article I observed that ornamental forms in many cases make utterance of truths which are so far hidden as to be imperceptible to the untutored, and this utterance was illustrated by reference to the Egyptian lotus, which spoke to those for whom it was intended of coming plenty, and thus became first looked for with pleasure, then reverenced, and finally worshipped as the abode or personification of a god.

Egyptian ornament is so full of forms which have interesting significance that I cannot forbear giving one or two other illustrations; and of this I am sure, that not only does a knowledge of the intention of each form employed in a decorative scheme cause the beholder to receive a special amount of pleasure when viewing it, but also that without such knowledge no one can rightly judge of the nature of any ornamental work.

There is a device in Egyptian ornament which the most casual observer cannot have failed to notice; it is what is termed the "winged globe," and consists of a small ball or globe, imme-

diately at the sides of which are two asps, and from which extend two wings, each wing being in length about five to eight times that of the diameter of the ball (Fig. 2). The drawing of this device is very grand. The force with which the wings are delineated well represents the powerful character of the protection which the kingdom of Egypt afforded, and which was symbolised by the extended and overshadowing pinions.

Fig. 2.

I know of few instances in which forms of an ornamental character have been combined in a manner either more quaint or more interesting than in the example before us. The composition presents a charm which few ornaments do, and is worthy of careful consideration. But this ornament derives a very special and unusual interest when we consider its purpose, the blow which was once aimed at it, and the shock which its perpetuators must have received, upon finding it powerless to act as they had taught, if not believed, it would.

The priesthood instructed the people that this was the symbol of protection, and that it so effectually appealed to the preserving spirits that no evil could enter where it was portrayed. With the view of giving a secure protection to the inmates of Egyptian dwellings, this device, or symbol of protection, was ordered to be placed on the lintel (the post over the door) of every house of the Egyptians, whether residence or temple.

It was to nullify this symbol, and to show the vain character of the Egyptian gods, that Moses was commanded to have the blood, of the lamb slain at the passover, placed upon the lintel, in the very position of this winged globe. It was also enjoined as a further duty, that the blood be sprinkled on the doorpost; but this was merely a new duty, tending further to show that even in position as well as in nature this winged globe was powerless to secure protection. This device, then, is of special interest, both as a symbolic ornament, and as throwing light on Scripture history

Besides the two ornamental forms mentioned, *i.e.*, the lotus and the winged globe, we might notice many others also of great interest, but our space will not enable us to do so: further information may, however, be got from the South Kensington Museum library*, where several interesting works on Egyptian ornament may be seen; from the "Grammar of Ornament" by Mr. Owen Jones, the works on Egypt by Sir Gardiner Wilkinson; and, especially, by a visit to the Egyptian Court of the Crystal Palace at Sydenham, and by a careful perusal of the hand-book to that court.† Much might also be said respecting Egyptian architecture, but on this we can say little; yet, as the columns of the temples are of a very ornamental character, we may notice that in most cases they are formed of a bundle of papyrus stems bound together by thongs or straps—the heads of the plant forming the capital of the column, and the stems the shaft (Fig. 3). In some cases the lotus was substituted for the papyrus,‡ and in other instances the palm leaf; these modifications can be seen in the Egyptian Court at Sydenham with great advantage, and many varieties of form, resulting from the use of the one plant, as of the papyrus, may also be observed.

Fig. 4.

We have here an opportunity of noticing how the mode of building, however simple or primitive in character, first employed by a nation may become embodied in its ultimate architecture; for, undoubtedly, the rude houses first erected in Egypt were formed largely of bundles of the papyrus, which were gathered from the river side—for wood was rare in Egypt—and, ultimately, when buildings were formed of stone, an attempt was made at imitating in the new material the form which the old reeds presented. But mark, the imitation was no gross copy of the original work, but a well-considered and perfectly idealised work, having the true architectural qualities of a noble-looking and useful column.

* Any person can have admission to the South Kensington Museum Art library and its Educational library, for a week, by payment of sixpence.

† A hand-book to each of the historic courts erected in the Sydenham Palace was prepared at the time the courts were built. These are still to be got in the literary department, in the north-east gallery of the building. They are all worthy of careful study.

‡ The papyrus was the plant from which Egyptian paper was made. It was also the bulrush of the Scriptures, in which the infant Moses was found.

We must now pass from the ornament of the Egyptians to that of the Greeks, and here we meet with decorative forms having a different object and different aim from those already considered.

Egyptian ornament was symbolical in character. Its individual forms had specific meanings—the purport of each shape being taught by the priests—but we find no such thing as symbolism in Greek decoration. The Greeks were a refined people, who sought not to express their power by their works so much as their refinement. Before the mental eye they always had a perfect ideal, and their most earnest efforts were made at the realisation of the perfections of the mental conception of absolute refinement. In one respect the Greeks resembled the Egyptians, for they rarely created new forms. When once a form became sacred to the Egyptians, it could not be altered; but with the Greeks, while bound by no law, the love of old forms was great; yet the Greeks did not seek simply to reproduce what they had before created, for they laboured hard to improve and refine what they had before done, and even through succeeding centuries they worked at the refinement of simple forms and ornamental compositions, which have become characteristic of them as a people.

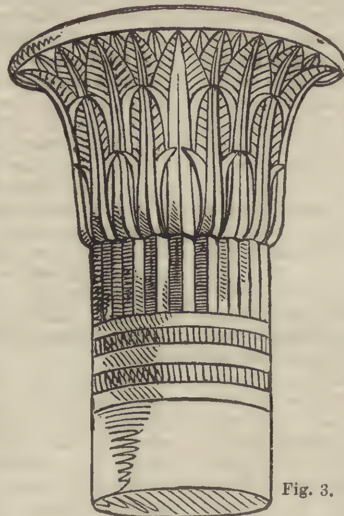


Fig. 3.

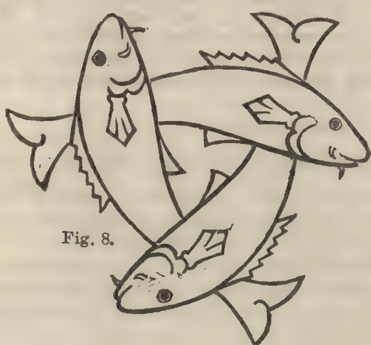


Fig. 8.

Fig. 7

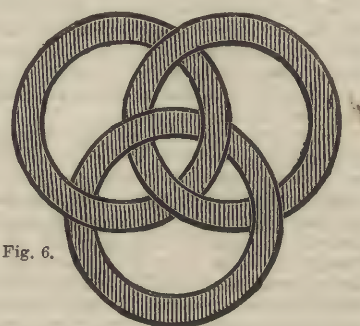


Fig. 6.

The general expression of Greek art is that of refinement, and the manner in which the delicately cultivated taste of some of the Greeks is expressed by their ornaments is perfectly astonishing. One decorative device, which we term the Greek Anthemion, may be regarded as their principal ornament—(the original ornamental composition by one of my pupils, Fig. 4, consists primarily of three anthemions)—and the variety of refined forms in which it appears is most interesting.

But it must not be thought that the Greek ornaments and architectural forms present nothing but refinement made manifest in form, for this is not the case. Great as is the refinement of some of these forms, we yet notice that they speak of more than the perfected taste of their producers, for they reveal to us this fact—that their creators had great knowledge of natural forces and the laws by which natural forces are governed. This becomes apparent in a marked degree when we inquire into the manner in which they arranged the proportion of the various parts of their works to the whole, and especially by a consideration of the subtle nature of the curves which they employed both in architectural members and in decorative forms; but into this matter we must not enter. Yet, by way of throwing some faint light upon the manner in which knowledge is embodied in Greek forms, I may refer to the Doric column, such as was employed in the Parthenon at Athens* (Fig. 5). The idea presented by this column is that of an energetic upward growth which has come in contact with some super-imposed mass, the weight of which presses upon the column from above, while the energy of the upward growth of the column causes it to appear fully equal to the task of supporting the superincumbent structure. Mark this—that by pressure from above, or weight, the shaft of the column is distended, or bent out, about one-third of the distance from its base to its apex (just where this distension would occur, were the column formed of a slightly plastic material), and yet this distension of the shaft is not such as to give any idea of weakness, for the column appears to rise with the energy of such vigorous life, as to be more than able to bear the weight which it has to sustain.

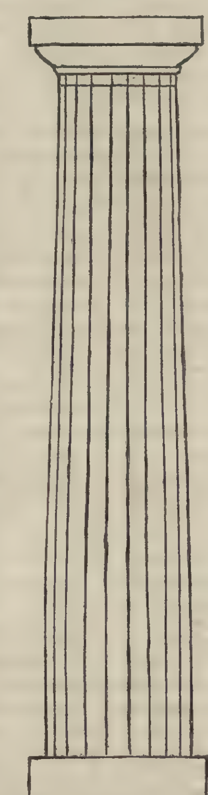


Fig 5.

Mark also the singularly delicate curve of the capital of the column, which appears as a slightly plastic cushion intervening between the shaft and the superincumbent mass which it has to support. The delicacy and refinement of form presented by this capital is perhaps greater than that of any other with which we are acquainted.

The same principle of life and energy coming in contact with resistance or pressure from above is constantly met with in the enrichments of Greek cornices and mouldings; but having called attention to the fact, I must leave the student to observe and think upon these interesting facts for himself. Let me, however, say that there are few classic buildings in England which will aid the learner in his researches; there is now but little poetry in architectural buildings, and but little refinement in the forms of the parts; and, added to this, Greek art without Greek colouring is dead, being almost as the marble statue to the living form. For the purposes of my readers, the Greek Court at the Crystal Palace will be the best example for study.

I might now review Roman ornament, and show that in the hour of pride the materials of which the works were formed were considered, rather than the shapes which they assumed; and how we thus get little worthy of praise from the all-conquering Romans—how the sunny climate and religious superstitions of the East called forth the gorgeous and beautiful developments of art which have existed, or still exist, with the Persians, Indians, Turks, Moors, Chinese, and Japanese; but

* A capital and portion of the shaft of one of these columns are to be seen in the British Museum Sculpture-room, and a cast of the same at the Crystal Palace, Sydenham. This Doric column is employed in the Greek Court of the Crystal Palace.

I have not space to do so; yet all the forms of ornament which these peoples have created are worthy of the most careful and exhaustive consideration, as they present art-qualities of the highest kind. I know of no ornament more intricately beautiful and mingled than the Persian—no geometrical strapwork, or systems of interlacing lines, so rich as those of the Moors (the Alhambraic)—no fabrics so gorgeous as those of India—none so quaintly harmonious as those of China; and Japan can supply the world with the most beautiful domestic articles that we can anywhere procure.

We must pass on, however, to what we may term Christian art, or that development of ornament which had its rise with the Christian religion, and has associated itself in a special manner with Christianity.

Neither the Egyptians nor early Greeks appear to have used the arch structurally in their buildings; the Romans, however, had the round arch as a primary element in the construction of their edifices. This round arch was also used by the Byzantines, and amongst their ornaments we find those combinations of circles and parts of circles, which we find so constantly recurring in later times in Gothic architecture and Gothic ornament. Norman buildings, again, show us the round arch, and present us with such intersected arcs as would naturally suggest the pointed arch of later times, with which came the full development of Gothic or Christian architecture and ornamentation. There was a very fine and marvellously clever development of decorative art, enthusiastically worked at by the Christian monks of the seventh and eighth centuries, called Celtic, of which we have many very beautiful examples in Professor Westwood's great work on early illuminated manuscripts; but what is generally understood by Christian or Gothic art had its finest development about the thirteenth century.

Gothic ornament, like the Egyptian, is essentially symbolic. Its forms have in many instances specific significance. Thus the common equilateral triangle is in some cases used to symbolise the Holy Trinity; so are the two entwined triangles. But there are many other symbols employed in Gothic ornament which set forth the mystery of the Unity of the Trinity. Thus in Fig. 6 we have three interlaced circles, which beautifully express the eternal Unity of the Trinity, for the circle alone symbolises eternity, being without beginning and without end, and the three parts point to the Three Persons of the Godhead. A very curious and clever symbol of the Trinity is portrayed in Fig. 7, where three faces are so combined as to form an ornamental figure.

Baptism under the immediate sanction of the Divine Trinity was represented by three fishes placed together in the manner of a triangle (Fig. 8); but so numerous were Christian symbols after the ninth century, that to enumerate them merely would occupy much space. Every trefoil symbolised the Holy Trinity, every quatrefoil the four evangelists, every cross the Crucifixion, or the martyrdom of some saint. And into Gothic ornamentation the chalice, the crown of thorns, the dice, the sop, the hammer and nails, the flagellum, and other symbols of our Lord's passion, have entered. But, besides these, we have more purely architectural forms making gentle utterance: the church spire points heavenwards, and the long lines of the clustered columns direct the thoughts upwards to heaven and to God.

Gothic ornament, having passed from its purity towards undue elaboration, began to lose its hold on the people for whom it was created, and the form of religion with which it had long been associated had become old, when the great overthrow of old traditions and usages occurred, commonly called the Reformation. With the reformation of religion came a revival of classic learning, and a general diffusion of knowledge, and thus the immediate necessity for art symbols was passing away, it being especially to an unlettered people that an extended system of symbolism appeals. With this revival of classic learning came the investigation of classic remains—the exploration of Greek and Roman ruins; and while this was going on, a dislike to whatever had been associated with the old form of religion had sprung up, which dislike turned to hate as the struggle advanced, till the feeling against Gothic architecture and ornament became so strong, that anything was preferred to it. Now arose Renaissance architecture and ornament (revival work), which was based on the Roman remains, but was yet remoulded or formed anew; so that the ornament of the Renaissance is not Roman ornament, but a new decorative scheme, somewhat of the same genus as that of the Roman. Here, however, all my sympathies end. I confess that all Renaissance ornament, whether developed under the soft sky of Italy (Italian ornament), in more northerly France (French Renaissance), or on our own soil (Elizabethan, or English Renaissance), fails to awaken any feeling of sympathy in my breast; and that it, on the contrary, chills and repels me. I enjoy the power and vigour of Egyptian ornament, the refinement of the Greek, the gorgeousness of the Alhambraic, the richness of the Persian and Indian, the simple honesty and boldness of the Gothic; but with the coarse Assyrian, the haughty Roman, and the cold Renaissance, I have no kindred feeling, no sympathy. They strike notes which have no chords in my nature: hence from them I instinctively fly. I must be pardoned for this my feeling by those who differ from me in judgment, but my continued studies of these styles only separate me further from them in feeling.

It will be said that in my writings I mingle together ornament and architecture, and that my sphere is ornament, and not building. I cannot separate the two. The material at command, the religion of the people, and the climate, have, to a great extent, determined the character of the architecture of all ages and nations; but they have, to the same extent, determined the nature of the ornamentation of the edifices raised. Ornament always has arisen out of architecture, or been a mere reflex of the art-principles of the building decorated. We cannot rightly consider ornament without architecture; but I will promise to take no further notice of architecture than is absolutely necessary to the proper understanding of our subject.

VEGETABLE COMMERCIAL PRODUCTS.—III.

PLANTS YIELDING SPICES AND CONDIMENTS (*continued*).

ALLSPICE, PIMENTO, OR JAMAICA PEPPER (*Eugenia Pimento*, De Candolle; natural order, *Myrtaceæ*).—This plant is called *allspice* because it has the combined flavour of all the other spices—that of cinnamon, cloves, and nutmegs entering into its composition. The unripe berries of this plant, dried in the sun, form the allspice. The plant itself is a handsome evergreen, with a straight trunk about thirty feet high, covered with a smooth, grey bark. Its leaves are opposite, short-petioled, elliptical, smooth, and pellucid-dotted, abounding in an essential oil, to which the pimento owes its aromatic properties. The flowers are greenish-white, and the fruit is a smooth, shining, succulent berry, black when ripe, and containing two uniform seeds, the flavour of which resides within the shell.

The allspice is a native of the West Indies, where it is cultivated—particularly in Jamaica, in the hilly parts of the country—in plantations, having broad walks between the trees, called "pimento walks." It begins to bear fruit when three years of age, and arrives at maturity in seven years. Nothing can be more fragrant than the odour of the pimento trees, especially when in bloom; even the leaf emits a fine aromatic odour when bruised.

The berries are collected before they are ripe, at which time the essential oil, to which they owe their pungency, is most abundant. They are spread out, exposed to the sun, and often turned. In about a week they have lost their green colour, and have acquired that reddish-brown tint which renders them marketable; they are then packed in bags and casks for exportation. When dried, the berries are rather larger than a peppercorn. Some plantations kiln-dry them, which expedites the process very considerably.

The consumption of allspice in this country is very great, as it is both cheap and useful; 22,000 bags, weighing 1,022 tons, were imported into Liverpool and London in 1850, and about one-fifth of that quantity was re-exported. This spice is used as a condiment, and its oil, like that of cloves, is employed as a remedy for toothache.

PEPPER (*Piper nigrum*, L.; natural order, *Piperaceæ*).—This is a climbing vine, with alternate, ovate, acuminate, dark-green leaves, five to seven-nerved beneath, and small inconspicuous flowers, in long, slender, drooping spikes, which are opposite. Its fruit is a round, sessile, one-celled berry, first green, then red, and finally black.

The pepper vine is indigenous to the East Indies, and is extensively cultivated in Sumatra, Java, and on the Malabar coast. A little pepper is also grown in the Mauritius and in the West India islands.

The berries, which resemble those of our holly in size and colour, are gathered as soon as they begin to redden; for if allowed to ripen fully, they lose their pungency. They are dried in the sun, and they become wrinkled and black on the outside. In this state they are known as black pepper, which is the most powerful variety.

White and black pepper are produced by the same plant. This difference in colour is only the result of a difference in the preparation of the berries. To obtain white pepper the berries are allowed to ripen, then dried and soaked in water, and the softened black outer coat is removed by rubbing. The internal seed is of a whitish-grey colour, and, when dried, forms white pepper.

Pepper is a warm carminative stimulant, which is added to food principally for the object of correcting the flatulent and griping character of certain articles of diet—peas and beans, for instance. Both varieties of black and white pepper are sometimes used whole in soups and pickles, but they are mostly ground in a mill, and sold in the form of a powder.

The quantity of pepper annually imported into the United Kingdom is immense. About 6,523 tons of the dried unripe black berries and white ripened seeds of the pepper plant reached this country from the East Indies in 1866, chiefly from Sumatra and Java, and also from Malacca, Siam, and Singapore.

The pepper vine is strictly tropical, but it will grow freely from cuttings wherever the soil and climate are suitable. It is allowed to climb props from ten to thirteen feet in height. These props root freely, the tree from which they are cut being selected with that object in view. The props thus afford both shade and support to the plants. Great care is necessary in the management of the vine, especially in training and tying it to the props. An acre of pepper vines affords an average annual yield of 1,161 lb. of clean pepper.

LONG PEPPER (*Piper longum*, L.; natural order, *Piperaceæ*).—This species, which is wholly different from the black pepper, is found wild in India, and is cultivated in Bengal. The long pepper consists of the fruit catkins of the plant dried in the sun. Long pepper is expensive, and therefore not much used either as a condiment or a medicine.

CAYENNE PEPPER (*Capsicum annuum*, L.; natural order, *Solanaceæ*).—Cayenne or red pepper is not the produce of a pepper plant, but of one belonging to a totally different natural order. It is prepared from the large, red, inflated, pod-like berries of the capsicum, dried and reduced to powder.

The capsicum is a native of the East and West Indies, but cultivated in England, where it can be grown with a very little care. There are numerous species of capsicum, named after the form and colour of the pod, which varies considerably. All are, however, included under the general Mexican name of "chillies."

In tropical countries chillies are used in great quantities, the consumption as a condiment being almost universal, and nearly equal to that of salt. In India they are the principal ingredients in all curries, and form the only seasoning which the millions of the poor of that country can obtain to eat with their insipid rice. The natives of the tropics can eat and relish them raw, which cannot be done by strangers from temperate climates without suffering, the pungent and acrid action of the chillies affecting the mouth and throat.

Capsicums or chillies are imported into this country in the form of red and brown pods, which are broken, dried, and packed in bales, weighing 2½ cwt., principally for making red pepper. Different varieties are cultivated for pickles, and are imported in the pickled state in vinegar from the East Indies. The annual imports from the East and West Indies are from 80 to 100 tons.

Capsicums are useful in cases of putrid sore throat, in malignant scarlet fever, as a powerful irritant to be applied in the condition of a saturated infusion externally, so as to draw the internal inflammation to the surface, and thus relieve the throat.

GINGER (*Zingiber officinale*, Roscoe; natural order, *Zingiberaceæ*).—This is an elegant, reed-like, tropical plant, which rises from a creeping rhizome or underground stem. The aërial stem is formed by the cohering bases of the leaves, which are alternate, lanceolate, and sheathing, the nervures diverging from the mid-ribs. The flower-stem springs from the rhizome. The dark-purple flowers are arranged in spikes.

The ginger-plant is a native of the East and West Indies, and is now cultivated generally in hot climates. The ginger of commerce is the dry, wrinkled rhizomes of the plant, which are called "races," and are usually from two to three inches in length, branched, flat, and white in colour. Sometimes the root is dug up when a year old, scalded to prevent germination, and then dried. So prepared, it is called "black ginger," although this term is very erroneous, as the darkest ginger is only a dirty stone colour. Again, the best pieces are selected, the outer skin is scraped off before the ginger is dried, and the pieces, bleached with chloride of lime, constitute what is known in the market as "white ginger." This bleaching process renders the ginger beautifully smooth, but certainly does not improve its quality. Lastly, the *races*, newly formed in spring, are cut off, and boiled in syrup; and the ginger, so treated, is imported in jars under the name of preserved ginger, forming a well-known sweetmeat.

The varieties of ginger recognised in commerce are the Jamaica white ginger, and the Jamaica and Malabar black gingers; also the black varieties, or the Barbadoes, African, and East Indian gingers. Jamaica ginger is considered to be the best. The amount of ginger annually imported into the United Kingdom is about 700 tons. The principal use of this spice is as a condiment. Medicinally, it is an excellent stomachic, removing flatulence and griping pains. When used in the form of a poultice, it forms a good rubefacient or counter-irritant.

VANILLA (*Vanilla aromatica*, Swammerdam; natural order, *Orchidaceæ*).—The vanilla is an epiphyte, or air-plant, with a trailing stem, not unlike the common ivy, which attaches itself to trees not as a source of food, like the mistletoe and other parasites, but as a mere point of support, deriving its nourishment entirely from the atmosphere. It grows from eighteen to twenty feet in length. The flowers are greenish-yellow mixed with white, and these are followed by a long slender pod, the fragrance of which is owing to the presence of benzoic acid, crystals of which form upon the pod if left undisturbed. This is, perhaps, the most important genus of the whole orchidaceous family, and the only one which possesses any marked economic value. It grows in the tropical parts of South America, in the Brazils, Peru, on the banks of the Orinoco, and in all places where heat, moisture, and shade prevail.

The pods or fruit of the vanilla are sub-cylindrical, about eight inches long, one-celled, and pulpy within, filled throughout their entire length with very minute black oily seeds, having the appearance of a black paste.

The following is a good account of the method used in preparing vanilla for market—"When about 12,000 of the pods are collected, they are strung like a garland by their lower ends, as near as possible to their foot-stalks; the whole are plunged for an instant into boiling water to blanch them; they are then hung up in the open air, and exposed to the sun for a few hours. Next day they are lightly smeared with oil, by means of a feather or the fingers, and surrounded with oiled cotton to prevent the valves from opening. As they become dry on inverting their upper end, they discharge a viscid liquor from it, and they are pressed several times with oiled fingers to promote its flow. The dry pods lose their appearance, grow brown, wrinkled, and soft, and shrink into one-fourth of their original size. In this state they are touched a second time with oil, but only very sparingly, because, if oiled too much, they would lose a great deal of their delicious perfume. They are then packed for the market in small bundles of 50 to 100 in each, enclosed in lead-foil or light metallic cases."*

As an aromatic, vanilla is much used by confectioners for flavouring ices and custards. The Spaniards employ it extensively in perfuming their chocolate. It is difficult to reduce it to small particles, but it may be sufficiently attenuated by cutting it into little bits, and grinding these along with sugar. The quantity imported into the United Kingdom is very small, amounting to not more than five and six cwt. per annum.

* See Ure's "Dictionary of Arts and Manufactures," Vol. III., p. 974. 1867.

SEATS OF INDUSTRY.—II.

SHEFFIELD.

BY H. R. FOX BOURNE.

Sheffield, smaller than Birmingham by about a third, is the second hardware town in England. It has an old as well as a modern history. A castle built on a field at the junction of the little river Sheaf with the Don, was the centre of the old lordship of Hallamshire in feudal times, and here Cardinal Wolsey was imprisoned for eighteen days, and Mary Queen of Scots for the best part of fourteen years. Before that, however, the village that had grown up round about began to follow the trade which, till very recently, has been the staple manufacture of the inhabitants. Chaucer speaks of "Sheffield whittles," and from an earlier day the rude knives so known, and other cutlery wares, were chiefly supplied to the Yorkshire districts by Sheffield, while Birmingham carried on a like trade with the midland counties. Neither town could then produce such delicate workmanship as some of the Continental factories. In the reign of Henry VIII. we read of "knives of Almayne, knives of France, and knives of Collogne," but only of whittles from Sheffield. The whittles gradually improved. A case of them was thought dainty enough to serve as a present from the Earl of Shrewsbury, lord of Hallamshire, to Queen Elizabeth. At that time there existed in Sheffield a corporation of cutlers, which in 1624, by charter from James I., became the Cutlers' Company that still has famous influence in the town. But Sheffield was then small and poor. In 1615 it had a population of 2,207, of whom, according to a contemporary record, 100 were "householders which relieve others, and though the best sort, are but poor artificers;" 160 were householders "not able to relieve others, such, though they beg not, as are not able to abide the storm of one fortnight's sickness, but would be thereby driven to beggary;" 1,222 were "children and servants of the said householders, the greatest part of which are such as live on small wages, and are constrained to work even to provide them necessaries;" and the remaining 750 were "all begging poor, not able to live without the charity of their neighbours." The inhabitants numbered 9,625 in 1736; 45,755 in 1801; and 185,157 in 1861. During the last two centuries the population has nearly doubled in every twenty-five years, and the importance of the town has grown in far greater proportion. Most of the 240,000 or more persons now resident in it are concerned, directly or indirectly, in the production of every sort of cutlery, from pen-knives to sword-blades, or of tools, trinkets, cannon-balls, and armour-plates, and the thousand other varieties of hardware manufacture, some of them peculiar to Sheffield, and others in which Sheffield is a formidable rival of Birmingham.

Steel is to Sheffield what brass is to Birmingham. Swedish iron comes into the town in vast supplies by way of Hull, and is skilfully worked up with the help of the coal that is plentiful in the neighbourhood. By far the larger part of the 50,000 or more tons of steel made annually in England—the produce of all the rest of the world being about as great—comes from Sheffield and its outlying districts, along the shores of the Don, and with this trade is extensively carried on the kindred and older process of cast-iron manufacture. Both cast iron and steel are combinations of pure iron and carbon, the proportion of carbon in cast iron being four or five times as great as in steel. All the efforts of old iron-workers were directed to the removal of every extraneous substance from the ore, so as to render it as ductile and malleable as possible. About 300 years ago it was discovered that the presence of carbon, while rendering iron less fit for ordinary purposes, gave it some special advantages, and accordingly the ore was so treated as that four or five per cent. of carbon should be left in it. The treatment, however, caused manganese and other bodies to be also left in the metal, and the presence of these substances lessens the value of cast iron for all delicate uses. To produce a suitable metal for these uses, therefore, the iron was at first purified as thoroughly as it could be, and then a portion of the carbon extracted from it was restored, the new metal being known as steel.

Most of the various methods adopted for thus manufacturing steel are pursued in Sheffield. In the Cyclops Works of Messrs. Charles Cammell and Co., the most common process, that of cementation, is pursued. The purest malleable iron, generally brought from Sweden or Russia, is broken into short bars, mixed up with powdered charcoal, and subjected to a uniform red heat for ten or eleven days, until a sufficient quantity of carbon is absorbed, and what, from its peculiar appearance, is called blister-steel is produced. Blister-steel is turned into cast steel by another melting and a slight hammering, or into shear steel by hammering alone. Coarser varieties are manufactured by modifications of this treatment, or by subjecting the cast steel to the ordinary puddling process until only the requisite quantity, from one-half to one per cent., of carbon is left in it. All these, however, are costly; and an important innovation is Mr. Bessemer's method of directly converting the crude metal, as it comes from the blast-furnace, into steel. The secret of this method is the sudden application of intense heat, under a rapid current of air, to the rough iron, whereby violent boiling and decarbonisation are secured, and tolerably pure steel is turned out with remarkable ease and speed. The process, invented in 1855, has yet to be thoroughly perfected; but vast benefits have already resulted from it. Not only is the manufacture of steel rendered much cheaper than by any other plan, but it can also be produced in larger masses than there were facilities for previously, and thus the metal can be applied to new and valuable uses.

One of these uses, directly due to Mr. Bessemer's fertile invention, is the manufacture of steel cannon-balls. "To facilitate this manufacture," says Mr. Fairbairn, "Mr. Bessemer designed a rolling-mill, now in use at his works in Sheffield, in which lumps of steel are fashioned into spherical balls, from 68 to 300 pounds each in weight, with the greatest rapidity, and with a degree of accuracy never attained in cast-iron shot. The mass to be acted upon is cut from a solid cylinder. The angles of the cylindrical lump are then reduced by pressure between curved surfaces. In this approximate form they are put, at a bright red heat, into the rolling-mill, which consists simply of a revolving table, in which an annular channel is formed. The channel being in section part of a circle of the diameter of the intended shot, a similarly grooved table is fixed above it. The axis of the lower one may be moved end-wise by a hydraulic ram, there being a recess formed in the ram to receive the end of the axis. When a mass of steel is put into this annular channel, and the table set in motion by powerful gearing, the hydraulic ram is made to act on the lower end of the axis, and compress the revolving mass between the grooved surfaces. The lump of steel in its passage round the central shaft also revolves on its own axis, which constantly varies in position, and thus ensures the most perfectly spherical form. To prevent the scale of the metal from roughening its surface, a jet of water passing down the hollow axis is projected against the shot as it revolves, and causes the scale to be thrown off as quickly as it is formed, while a blast of air passing down another passage in the axis blows all these detached scales out of the annular channel. Three balls are best acted upon at one time, so that in three or four minutes this simple apparatus is capable of producing three large spheres, more accurate in size and form than a workman with a slide-lathe could produce in as many days." That "simple apparatus" will serve as a specimen of the numberless methods by which mechanical skill is made to supersede, or rather to economise, hand labour in Sheffield, as in all other manufacturing towns.

A more important illustration of the way in which warlike needs are served in Sheffield, to the great enrichment of the town, is furnished by its manufacture of armour-plates. Iron ships have already virtually superseded the more graceful wooden men-of-war for purposes of naval fighting; but their adoption was long delayed by the peculiar dangers arising from the effects of shot upon ordinary iron steamers. The innovation was opposed by the English Admiralty in 1834 and subsequent years, until 1855, when the Emperor Napoleon caused thick iron plates to be constructed for casing the sides of his iron warships, and their successful use in the Crimean war brought iron-clads into fashion. The Sheffield manufacturers quickly set themselves to supply the new commodity. Messrs. John Brown and Co., who started their huge Atlas Works in 1857, began the enterprise in 1860. They constructed immense rolling-mills adapted for the production of armour-plates, some of them twelve inches thick, nineteen feet long, and four feet wide, and weighing twenty tons. Their example was soon followed by

Messrs. Cammell and Co. at their Cyclops Works, and thus the two largest establishments in Sheffield find a considerable part of their business in providing the munitions of war.

Armour-plates, however, are only special items in the multitudinous productions of these great hardware factories. Other factories have their own specialities; among the most notable being the steel cannon-balls of Messrs. Thomas Firth and Sons, who follow in Mr. Bessemer's lead, using their own homogeneous steel in lieu of the Bessemer steel; the saws of Messrs. Spear and Jackson, manufactured at their Ætna Works; and the cast-steel bells of Messrs. Naylor, Vickers, and Co. Making bells weighing 2,000 or more pounds apiece, the latter firm has proved that steel is for this purpose as serviceable as bronze, and nearly two-thirds cheaper.

These new manufactures have partly ousted knife-making from its old place as the staple trade of Sheffield; but Sheffield is still the great haunt of cutlers, some 1,500 employers having here their workshops, besides about 250 makers of files, while the makers of edged tools number about 150, the saw-makers as many, the makers of hammers about 60, and the engineers' tool-makers about 100. These associated trades provide occupation for a large part of the community, and in them all the appliances of modern science and art are brought to bear. Each one of the millions of pen-knives manufactured every year in Sheffield, and sent for sale to all quarters of the world, goes through ten or a dozen hands. One man forges the blade; another roughly grinds it; a third softens the metal and affixes the trade-mark of the maker; a fourth hardens and tempers it; a fifth grinds it over again until a fine edge is produced; a sixth fastens it to the handle, which has been prepared by a separate train of workpeople, from wood, horn, ivory, mother-of-pearl, or any of the other substances employed. In file-making and all the other trades of the town there is a like subdivision of labour.

Wire manufacture is another important trade of Sheffield, some wire, for watchmakers' use, being so fine that a hundred miles' length of it would hardly weigh a pound. When steel wire was in fashion for ladies' crinolines, Sheffield produced 10,000 tons of it in a year.

The trade in which Sheffield competes most directly with Birmingham is that concerned in the manufacture of plated goods. This trade was born in the Yorkshire town. In 1742 one Thomas Bolsover was employed to repair the handle of a knife made partly of silver and partly of copper. It occurred to him that, by placing a thin coat of silver over a thick base of copper, and rolling them together at a high temperature, they might be welded into one mass, and a marketable commodity produced. He experimented successfully, and soon drove a thriving trade in plated snuff-boxes, buttons, and the like. Matthew Boulton adopted the device in Birmingham, and before long both towns were busy with silver-plating and gold-plating. The electro-plating process, begun at Birmingham a century later, was soon copied in Sheffield, and thus each town has helped the other to a new source of wealth. The kindred trade in Britannia metal—an amalgamation of tin, regulus of antimony, copper, and brass—was started in 1770 by two Sheffield workmen named Jessop and Hancock, and now gives employment to one large house and many smaller ones.

Rivalling Birmingham in the general character of its employments, and especially in some of their details, Sheffield differs widely from it in one important respect. The Warwickshire hardware town is a model of freedom from restraint among workpeople, and of harmony between them and their masters. The Yorkshire hardware town, as was painfully shown a few years ago, furnished an ugly example of the tyranny of trades' unions, and of the mischievous disposition that leads to strikes and trade-outrages. The social condition of the workpeople, who are generally paid highly for the skilled labour of which they are masters, is favourable; and there is now no counterpart to the state of things which, as we have seen, prevailed in the town 250 years ago, when one-third of the inhabitants were "begging poor," and most of the rest were "constrained to work even to provide them necessaries." There are signs of wealth in the cottages as well as in the mansions; but the very prosperity of the labourers has begotten an evil. Jealous of all rivalry, they strive, by foul means as well as fair, to maintain their advantage over the majority of English workpeople. The result is a vicious temper, which dominates the whole class, though most of its members may be free from it, and which threatens to retard the future growth of Sheffield, and drive some of its trades into healthier homes.

APPLIED MECHANICS.—II.

BY ROBERT BALL, M.A.

THE PULLEY.

INTRODUCTION—LARGE AND SMALL PULLEYS—THEORY OF THE PULLEY-BLOCK, INCLUDING FRICTION—EXPERIMENTS UPON THE THREE-SHEAVE PULLEY-BLOCK.

Before commencing this lesson the student should make himself familiar with what has been said on the subject of Pulleys in Lessons X., XI. of the series of lessons on "Mechanics." It will also be necessary to fully understand what is in Lesson XI. called the "golden rule of Mechanics." This law may be thus stated:—

In any mechanical power the distance through which the power moves multiplied by its magnitude is equal to the distance through which the resistance moves multiplied by its magnitude.

This rule must be thoroughly grasped before any real advance can be made in the practical side of the subject which we now approach. It is often called the "law of virtual velocities," and we shall use this name, though in reality virtual velocities means a general and profound truth in Mechanics, of which the golden rule is only a particular case. We shall also use the term *velocity ratio;* this may be defined as the proportion of the distance though which the power moves in a given time to the distance over which the load is moved in the same time. It would follow then, from the principle of virtual velocities, that the mechanical efficiency of a machine is to be expressed by its velocity ratio. This is the usual supposition, and by it various problems in pulleys are solved in Lesson XI. But when we turn to practice, we find that the mechanical efficiency of a pulley is very much less than its velocity ratio. This is because friction has stepped in and robbed us of our force. No matter how well made be the axles and their bearings, no matter how carefully they be oiled, there is invariably loss of power produced by friction. The student will do well to read the account of friction given in Lesson XII. It is the presence of this force which imperatively demands that to study the mechanical powers we must first resort to experiment, and then theory will aid us in making our experiments, and afterwards discussing them. We shall find that friction, which at first sight seems embarrassing, and destructive of whatever is symmetrical or elegant in the treatment of the problem, does not really prove so: on the contrary, it leads, when properly studied, to truths of a beauty and profundity beyond any we can attain by theoretical studies of the mechanical powers which do not recognise its presence.

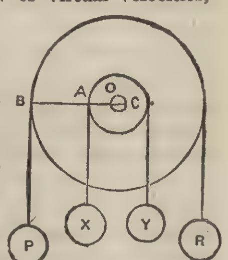


Fig. 1.

EXPERIMENTS ON LARGE AND SMALL PULLEYS.

We shall commence our experiments upon a single pulley, which is merely used for the purpose of changing the direction of a force. This can only be done at a little sacrifice of power, whatever be the size of the pulley; but the loss is greater with a small pulley than a large one. We can study the subject by the apparatus of Fig. 1. This represents an horizontal axle around which the piece A B is capable of turning quite freely. A B is apparently composed of two pulleys fastened together; it is in reality one piece, one of these sheaves being 4·7 times the size of the other. We may place the rope on either the larger groove or the smaller groove, as is shown in Fig. 2. We shall first describe the mode of experimenting with the larger groove, and the same process is to be afterwards carried out with reference to the smaller groove. A rope being placed on the pulley, let a weight, R, be hung at one end. If then an equal weight, P, were placed on the other side, the two would balance. Now, if the pulley

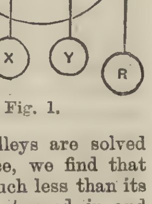


Fig. 2.

had no friction, we should find that the slightest addition made to either of the weights would cause it to descend and raise up the other; but on account of friction, a very appreciable addition must be made to one of the weights before it does this. We shall give the details of one experiment, in which a piece of flexible rope was used, which carried a hook fastened to each end, the hooks having equal weights. A weight of 14 lb. was then placed on each of the hooks. We have now a number of pieces of wire, each of which weighs exactly 0·1 lb. We add one of them to P, but there is still equilibrium, 0·1 lb. not being sufficient to overcome the friction; another and another is added, till we find that when P has received 0·4 lb. it begins slowly to descend; the friction is then conquered, and it is measured by 0·4 lb. Let us now remove the stone weights from the two hooks, and attach to them weights of 56 lb. each. We find that 0·4 lb., which was sufficient to overcome the friction before, is not now enough; 1·2 lb. must be added to the weight P before it descends and raises R. This experiment teaches us that the friction of a pulley about its axle increases with the weights that the pulley is lifting: here the weights are increased fourfold, and the friction has increased threefold. Speaking very roughly, we may often take the friction as proportional to the load raised. This rule gives rather too high a value for large weights, and too low for small weights, but it may be taken as sufficiently correct for ordinary purposes.

Let us remove the rope from the large groove, and place *it* on the small groove, adding 14 lb. to each of the hooks. The condition of things is so far the same as in the first of the two cases already described, that the two grooves turn as one piece upon the same axle; if, therefore, we find any difference in the amount of friction, it is to be attributed solely to the difference in the size of the two grooves. We load P as before, but we find before it descends we must add to it 3·6 lb.; this, then, is the measure of the friction. It is nine times as large as it was when we used the larger pulley. This difference is not to be attributed to friction only; the rope opposes more resistance to being bent around the small pulley than it does about the large pulley, and this resistance and the friction account for the loss.

It will be easy, by examining Fig. 2, to see that friction must have a greater effect on the small pulley than on the large pulley. The friction is at the circumference of the axle, and always acts to oppose the motion. Supposing P be acting to raise R, P acts at an arm O B, while the friction acts at the arm O C; the leverage of P, therefore, in overcoming the friction is greater than that of X in the proportion of the lengths O A and O B; hence the friction should be 4·7 times larger in the small pulley, that is,

$$4{\cdot}7 \times 0{\cdot}4 = 1{\cdot}88 = 1{\cdot}9 \text{ lb. approximately.}$$

The difference between this amount and that which was observed,

$$3{\cdot}6 - 1{\cdot}9 = 1{\cdot}7 \text{ lb.},$$

expresses the power that is expended in overcoming the other source of loss, viz., the rigidity of the rope.

The practical conclusion to be derived from these considerations is this: always use pulleys as large as possible. In coal-pits the cage containing trucks of coal is raised to the surface by a wire rope; this generally passes over a large pulley, and from thence to the engine-house. The pulley is large, both for the purpose of avoiding friction, and also to avoid bending the rope too quickly, a process that not only entails loss of power, but also injures the rope. By having a large pulley for the rope to pass over, sudden flexure is not required. The pulleys used in coal-mining are from six or eight feet in diameter up to nearly double this size.

THEORY OF THE PULLEY-BLOCK, INCLUDING FRICTION.

Let n be the virtual velocity of a pulley-block, or, indeed, of any other mechanical power, for the investigation now given applies to all machines.

Let R be the load to be raised, P the power which raises it. If there were no friction, we should have

$$P = \tfrac{1}{n} R;$$

but the presence of friction prevents this equation being true. The power required is always greater than the value given by it.

It is found that the power should be expressed by a formula of this kind—

$$P = A + BR,$$

where A and B are numerical constants whose values must be determined by experiment. The form of this expression should be noticed. Friction is not strictly proportional to the pressure. It is found that the friction is best represented by two terms: one, B R, which bears a certain ratio to the load; the other a constant quantity, A, which is generally small. A also implicitly contains the amount of power necessary to raise the actual weight of the lower block; so that R means only the actual number of pounds attached to the hook. We can easily conceive how A and B can be determined.

Suppose we hang a load, R_1 to the load-hook, and find that a power, P_1, is necessary to raise it, we have, by the formula—

$$P_1 = A + BR_1.$$

If now we take another load, R_2, and find the power to raise it be P_2, we have—

$$P_2 = A + BR_2.$$

There are thus two equations between the two unknowns, A and B. From these two equations the values of A and B can be determined by the well-known process which is described in Lessons in Algebra. It will then be found that if any other load, R_3, be raised, the power necessary to lift it will be

$$A + BR_3,$$

thus verifying the formula. Actual values of A and B for one system of pulleys will presently be given. They are found by taking the mean of several different experiments. The principle is essentially the same as here explained, but is a little more accurate. It need not be dwelt on further, as the process is somewhat difficult, and requires considerable calculation.

Let us now deduce from this formula the mechanical efficiency of the machine. This is to be obtained by dividing R by A + B R. We have for quotient—

$$\frac{R}{A + BR} = \frac{1}{B + \frac{A}{R}}.$$

When R is considerable, $\frac{A}{R}$ is very small, and therefore the mechanical efficiency is represented by $\frac{1}{B}$ very nearly.

It will also be useful to ascertain the quantity of energy or work which is usefully employed, and therefore, of course, the quantity which is wasted in overcoming friction. In order to raise R pounds one foot, P must be exerted over n feet, hence n P units of work must be expended to do R units of work; but

$$nP = nA + nBR;$$

and out of this quantity only R is employed, hence the percentage is

$$\frac{R}{nA + nBR} \times 100$$

$$= \frac{100\,R}{n(A + BR)}$$

$$= \frac{100}{n\left(\frac{A}{R} + B\right)}.$$

If R be very large, $\frac{A}{R}$ is small, and may be neglected; and we find the per-centage of work utilised to be

$$\frac{100}{nB}.$$

TECHNICAL DRAWING.—VI.

DRAWING FOR CARPENTERS—COFFER-DAMS (*continued*).

FIG. 31 is the section of a much stronger coffer-dam, which is so constructed as to preserve its firmness throughout its entire height. This consists of three rows of piles, *a b c*; the two nearest the water, *a* and *b*, being of the full height of the coffer-dam, and the third, *c*, being half the height. These piles are placed at certain distances apart, and are united at the top and at a point just below the middle by cross-timbers, d^1, d^2, placed horizontally on each side of the piles, and attached by being notched on to the piles; an iron bolt passing through all three timbers. The outer row of piles are connected in a similar manner by the cross-pieces, *e*, which are on a level with the rails, d^1 and d^2. Resting on these, timbers, *f*, are laid across

in pairs—that is, on each side of the piles, so that each pair grasps the piles, and also the strut, *g*, between them; bolts tightened up by means of nuts passing through all three. The transverse pieces at the top of the long piles rest on the longitudinal joists, and are in this example shown notched down upon them, for the purpose already explained in the previous study.

The student must now be reminded that up to this stage the construction is a mere skeleton, the piles being six or eight feet apart. This space is filled in by *sheet*-piling—that is, piles placed in a *sheet* or wall. These are narrower than the true piles, and are driven down between the longitudinal cross-pieces or walls, so as to render the whole construction complete.

This hollow wall is now to be filled in with clay, puddle, etc., and the water having been pumped out of the site enclosed by the coffer-dam, the ground must be dredged, and, if required, a bed of *béton** must be laid down on which to erect the intended pier or other structure.

The following practical hints by Mr. Dobson are quoted for the instruction of the student:—"Leakage between the puddle and the surface of the ground will generally take place unless all the loose, soft, or porous surface-soil be carefully removed by dredging before the puddle is put in. This dredging may be done before or after the piles have been driven. Leakage through the puddle-wall itself may arise from various causes, but may generally be prevented by careful work, and selection of good materials. In the first place, the piles should all be fitted to each other before driving, and should be truly and carefully driven: next, the framing and strutting should be sufficiently strong to prevent any straining or movement under the varying pressure to which the dam may be exposed by alternations in the height of the water; and lastly, the material used for the puddle should be such as will settle down into a solid mass, and should be carefully punned in thin layers so as to secure that no vacuities are left in any part. For this reason it is desirable, when the piles have been driven between the double wallings, to remove the inside walls after the piles are home, as any projections of this kind increase the difficulty of punning the puddle. In order to resist the evil effects which might arise from the swelling of the puddle, the inner and outer rows of piles are usually connected with iron bolts passing through the piles, and secured by nuts, with iron plates and large wooden washers to prevent the former from being drawn into the piles by extreme pressure. These tie-bolts are often found to be very troublesome sources of leakage, as the water soaks in round the bolt-holes, and it is difficult to keep the puddle from settling away from the bolts, and leaving a channel for the passage of water through the dam."

With this information as to the construction of the coffer-dam, the student will not, it is presumed, require any instructions as to copying the example; and he will, as has been already mentioned, do well to draw the various parts in precisely the same order in which they have been mentioned in the description.

WOODEN BRIDGES.

Wooden bridges may be looked upon as the origin of all other constructions for crossing water or roads, whether of stone or iron; for it seems natural to suppose that in the earliest times the simple method of throwing a plank across a stream may have been adopted—in fact, the falling in that position of a tree on the bank would have suggested such an expedient.

A plank placed across from one bank of a stream to the other is, then, the most elementary form of a timber bridge; it is at the same time the most perfect, and the principle on which it is suspended, or kept in its proper position, is worthy of consideration. "For," says Mr. Peter Nicholson, "we may learn how to construct the best and most advantageous kind of bridge suitable for immense spans from this unpretending and apparently unpremeditated contrivance."

When a strong plank is thus laid upon two supports, that part of it which lies midway between them has to sustain its own weight, and that of anything crossing over it, by the cohesion between its particles—that is, by the power with which the atoms or fibres of which it is built up, cling together; for as that part of the plank has nothing to rest upon, it will be clear that it will have a tendency to break somewhere between the supports when the strain upon it exceeds its strength.

But owing to the cohesion of the particles, which attracts them one to another, such a plank cannot snap asunder with absolute suddenness, because the cells of which timber is formed are lengthened out into fibres or hollow threads, and these are so interwoven one with another that one particle or atom of the material will not readily be separated from its fellow as long as such material remains in a sound state.* This being the case, the weight upon the beam will cause it to bend, or what is technically termed to "sag," and it is to prevent such bending extending beyond a safe amount of elasticity that the efforts of the constructor of wooden bridges are mainly directed.

Absolute construction does not come within the province of these lessons, but, as already stated, the better acquainted a man is with the principles involved in what he is doing, the better will he do his work, and certainly the more interest will he take in it; and therefore, although nothing like a scientific treatise would be in character with the object in view, it is hoped that the following notes on wooden bridges, their history, and peculiarities of construction, may be of interest to those who are now, or who may at any time become, engaged in such works.

It will be easily understood that when a plank is laid across from wall to wall, and a weight is placed on any part of it, it bends, because the particles of which it is formed are pressed close together on the upper side, whilst on the under side they are drawn out. If across a plank so placed you had previously drawn lines exactly corresponding with each other, you would find that when a weight is placed on the plank the lines on the lower will be further apart than those on the upper surface. Thus you will understand that two forces are acting on the beam at the same moment, for the upper portion is subjected to a *compressing* force, whilst a tensile or *stretching* force is acting upon the lower side.

It is the strength with which these two forces counteract each other that constitutes the rigidity of timber, and it will be evident that there must be some intermediate plane between the upper and lower surfaces of the beam in which the two opposite contending forces will meet, in which, of course, neither will preponderate. This is denominated the *neutral plane*, and will be differently situated according to the thickness of the beam, and the power of cohesion which is possessed by the fibres of the various kinds of timber.

In looking back to the early history of wooden bridges, we shall find that where rivers were broad and their channels deep, it would be impossible to cross them by single beams of timber. In such cases a timber framing or scaffolding would be formed in the bed of the river by driving piles, or a pier might be formed of stones or other materials. On these, beams of timber would be placed with one extremity resting upon the pier, and the other on the bank of the river, or on an abutment raised at the water's edge, and upon several piers in the water, as the case might be.

Where the distances between the supports were too great for the dimensions of the timber forming the roadway, the main beams were propped up by struts projecting from the sides of the piers or piles, which were sometimes made to meet in the centre; or if that was not practicable, on account of the distance between the supports, they could each be made to sustain the beam, either by running directly to it from the abutment at about an angle of 45°, or a cross-piece, on which their ends should abut, be placed between them and fastened to the under side of the beam. These struts or stays were then multiplied and disposed in various ways, until at length a rib or arch of timber was formed to support the roadway, while the spandrels † were filled up with struts and ties to resist compression.

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* *Béton*, a kind of concrete, which, owing to its composition, has the property of hardening under water. (See "Lessons on Building Construction.")

* For an account of wood, and how it is formed, see "Our Houses," and "The Uses of Plants" (Cassell's Primary Series).

† *Spandrel.*—The irregular triangular space bounded on one side by the curve of the arch, on the second by the vertical, and on the top by the horizontal lines forming the sides of the angular space in which an arch is contained.

The ribs of bridges constructed in this manner were composed of frames, the lower portion of which form segments of circles, frequently made up of several pieces of wood placed immediately over each other and joggled together, so arranged however, that their ends should break joint. To these circular arcs, or polygonal frames, upright pieces were attached, either by bolts, mortises, or iron straps, by which the weight of beams supporting the roadway was sustained at intervals, and so disposed as that each part might, as far as possible, conduce to the strength of the whole.

The following historical notes as to timber bridges are given in order that the student may glean some intelligence as to what *has been* done—the best possible guidance as to what *may be* done. The extensive use of iron in tubular, girder, and suspension bridges, has in modern times superseded, in a great degree, the use of wood, but not entirely so; and as the principles are applicable to so many other timber constructions, no apology will be necessary for describing some of them, especially as they constitute, both in their complete form and in their details, such excellent studies in drawing for all those engaged in wood-work.

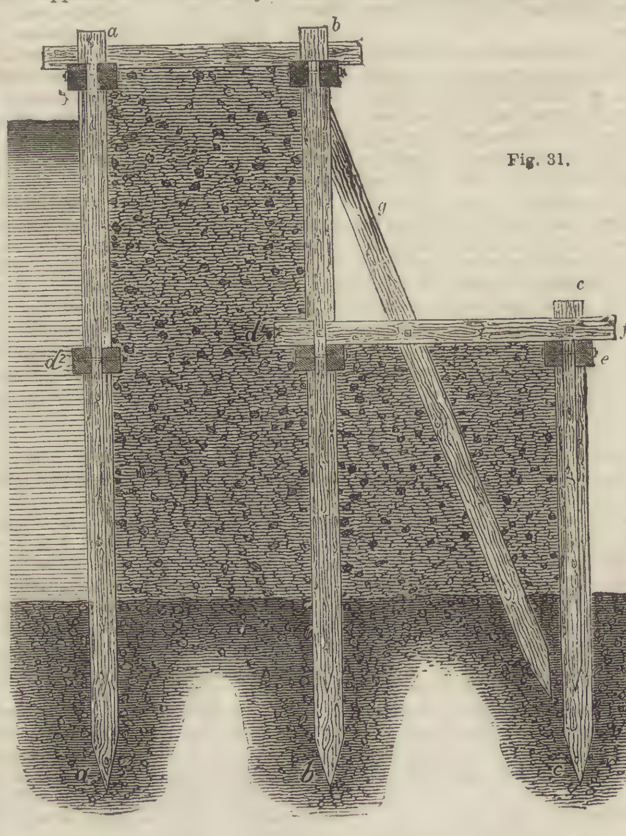

Fig. 31.

The "Pons Sublicius" was the first bridge ever built across the Tiber. It was at first constructed of timber in the reign of Ancus Martius. *It was put together without either bolts or ties*, so that it could readily be taken asunder, and was built for the purpose of connecting together the Aventine and Janiculum hills.

The bridge over the Danube, by Trajan, is almost one of the oldest timber bridges of which we have a detailed account.

It was supported on *twenty stone piers, which were* 150 *feet high and six feet broad.* On these were framed timber arches each 170 feet span, and formed of three concentric timber rings bound together by radiating pendants. These, together with the arches, supported the longitudinal beams on which the flooring joists were placed across the bridge.

The timber bridge of Schaffhausen, built over the Rhine by Ulrick Grubenmann, was remarkable for its ingenious construction. It consisted of two openings, one of 170 feet span, and the other about 190. Its abutments and centre pier were of stone. On these were laid a kind of compound beam formed of three rails or walings, each of which consisted of two longitudinal beams bolted together and toothed into each other so as to be perfectly united; these were supported by an infinity of struts, kept in their places by vertical binding pieces, *all tending to transfer the thrust to the supports* of the bridge. It was roofed in for the ostensible purpose of protecting the timber, but there can be no doubt that the roof added greatly to its strength. This bridge (which was demolished in the year 1800), and others designed by the brothers Grubenmann, were, in fact, timber tubular bridges.

The timber bridge of St. Clair, over the Rhone at Lyons, has seventeen openings, the centre one having a span of forty-five feet, and the others diminishing towards each bank. This bridge has a roadway of about thirty-six feet, which is supported upon piers, each formed of thirteen piles arranged in a single row, running parallel with the banks of the river. On the top of these piles a sill was framed, and longitudinal timbers were made to bear over the head of each pile, and upon these the flooring of the bridge was laid.

The bridge of Grenelle, over the Seine near Paris, built by M. Mallet, consists of two equal and symmetrical bridges, separated by an intermediate piece of dry ground; each of these is formed of three timber bays of eighty-two feet span, *supported upon two abutments and two piers of masonry.* The width of this bridge is nearly thirty-three feet. The ground in the centre measuring eighty-five feet, the whole bridge, reckoning the entire distance from the abutments on either side of the Seine, is 632 feet long. All the foundations were built on piles, upon which a planking was laid.

These foundations were formed by means of coffer-dams, which at low water were not more than five feet deep. A bridge similar to this was built over the Seine at Ivry in 1828.

Besides these, which are merely mentioned as well-known specimens, there is an almost endless number of wooden bridges erected throughout the world, amongst which may be named that at Trenton, in America, of 180 feet span; a bridge over the Tees, 150 feet span; the bridge of Neucetringen, in Bavaria, 102 feet span; that over the Necker, 210 feet span; the bridge of Bamberg, with an opening of 206 feet, erected by M. Wiebeking, an engineer who has constructed an immense number of timber bridges; the bridge of Feldrick, with a span of 65 feet; the bridge of Zeto, built by M. Coffinet, with a span of 125 ft.; besides several put up by the celebrated M. Perronet, a French engineer, who was extremely skilful in forming constructions of this kind.

Before giving some examples for drawing purposes, acting upon my often-repeated wish that my readers should consider drawing as a mental as well as a manual exercise, I ask their attention to the following principles of construction.

Timber bridges are either supported upon piers and abutments of masonry, built on the solid foundation of the ground, or on a platform constructed upon piles driven into the earth, or they are supported upon piers formed upon one or more rows of piles driven in a line with the road or river passing under the bridge. There is almost an infinite variety of ways in which such props or piers may be made. It is, however, usual to drive the piles about a yard apart, from centre to centre, and to bolt capping-pieces or walings to the top of such piles, and either filling up the spaces between with large stones laid dry or else grouted with mortar. On this the masonry for the supports should be placed, or a timber framing, if desired, or else the piles may be carried up to the height of the roadway, being kept in their places by walings and diagonal pieces, bolted on each side of them. These piles should be about a foot square, and when they are driven in salt water or in tidal rivers, their surfaces, up to high-water mark, should be sheathed with copper, or otherwise protected from the ravages of the worm.

BUILDING CONSTRUCTION.—IV.

FOUNDATIONS.

It will be remembered that the term *foundation* refers not only to the surface or bed on which a building stands, but to the manner in which the lower portions of the walls are constructed.

Now, as walls are built either of stones or brick, we think it advisable to give the principles connected with the laying of both these materials before proceeding with the subject of the foundations in which they are to be employed; otherwise several of the terms used might not be understood by the beginner

MASONRY.—PART I.

Stonemasons class the methods of building walls into (1) *rubble work* and (2) *ashlar work.*

Rubble work is either *uncoursed* or *coursed.*

In *uncoursed rubble* (Fig. 6), stones of any size and shape are used without any reference to their heights. The workman merely uses a tool, called the *scabling hammer*, to chip off any portion which may be unsightly or project from the general surface of the wall; an intelligent mason is, however, careful so to dispose his variously-shaped stones that they may fit into each other, packing in every interstice with smaller stones, filling in every crevice with mortar, and using his plumb-rule to keep his wall perpendicular. It must be borne in mind that the wall is to be composed of stone, which is compact, and mortar, which is yielding; and therefore the more stone, and the less mortar put in, the better. As the mortar will continue to shrink until it is dry and hard, it will be easily understood that a thick bed of soft material will necessarily allow of a greater settlement at the part where it exists than in any other; nor should any stone be placed so as to rest on one part which may project more than another, and be bedded up with mortar, which would, of course, cause unequal settlement when other stones are placed upon it. It will thus be seen that even in the simplest operation there is a scope for intelligent application of thought, and necessity for knowledge of principles.

Fig. 6.

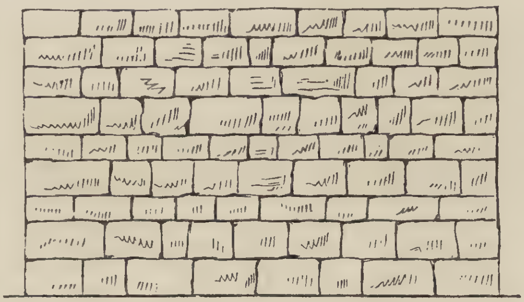

Fig. 7.

Fig. 8.

In *coursed rubble* (Fig. 7), the workman roughly dresses the stones before he begins to lay them. He is careful to get good beds to them, that is, to get the under and upper surfaces of the stones perfectly parallel; he also gets the front of them at right angles to the beds, and tolerably level. The wall is built in courses, which are kept of one height all along in each, although the different courses need not be equally high, nor need the separate stones of which a course may be composed necessarily be equal, but some may be laid on others to make up the height. The stones at the corners are called "quoins," and are always laid with care, as they serve as gauges by which the height of the course is regulated, the workman using the line and level to guide him.

Ashlar work (Fig. 8) is a sort of facing to a wall built either by one of the other methods or of bricks. Ashlar stones, or ashlars, as they are usually called, are neatly squared and tooled on their surface, and are made of various sizes according to convenience or the character of the building. The following is given on the authority of Mr. Peter Nicholson:—

Walls are most commonly built with an ashlar facing, and backed with brick or rubble work. Brick backings are common in London, where bricks are cheaper; and stone backing is the north of England and Scotland, where stone is plentiful. Walls faced with ashlar and backed with brick or uncoursed rubble are liable to become convex on the outside, from the greater number of joints and from the greater quantity of mortar placed in each joint, as the shrinking of the mortar will be in proportion to the quantity; and therefore a wall of this description is much inferior to one of which the facing and backing are of the same kind, and built with equal care, even though both sides were uncoursed rubble, which is the worst of all walling. Where the outside of a wall is of ashlar facing, and the inside coursed rubble, the courses of the backing should be as high as possible, and set in thin beds of mortar. In Scotland, where stone abounds, and where perhaps as good ashlar facings are constructed as any in Great Britain, the backing of the walls most commonly consists of uncoursed rubble, built with very little care.

In the north of England, where the ashlar facings of walls are done with less neatness, they are much more particular in the coursing of their backings. Coursed rubble and backings are favourable to the insertion of bond timbers; but in good masonry wooden bonds should never be in continued lengths, as in case of fire or rot the wood will perish, and the masonry, being reduced by the breadth of the timbers, will be liable to bend at the place where it was inserted. When it is necessary to have wall timber, for the fastening of battens for lath and plaster, the pieces of timber ought to be built with the fibres of the wood perpendicular to the surface of the wall, or otherwise in unconnected short pieces not exceeding nine inches in length.

In an ashlar facing the stones generally run from twenty-eight to thirty inches in length, twelve inches in height, and eight or nine inches in thickness. Although both the upper and lower beds of an ashlar, as well as the vertical joints, should be at right angles to the face of the stone, and the face-bed and vertical joints at right angles to the beds, in an ashlar facing, where the stones run nearly of the same thickness, it is of some advantage in respect of bond that the back of the stone should be inclined to the face, and that all the backs thus inclined should run in the same direction, as this gives a small degree of lap in the setting of the next course; whereas, if the backs were parallel to the fronts, there could be no lap where the stones run of an even length in the thickness of the wall. It is of some advantage, likewise, to select the stones so that a thicker and a thinner one may follow each other alternately. The disposition of the stones in the next superior course should follow the same order as in the inferior course, and every vertical joint should follow as nearly as possible in the middle of the stone below.

By the term *beds of a stone* is meant the upper and lower surfaces of the block. In usual walling these are horizontal,

viz., at the right angle with the face, and are called the lower bed—that is, the one on which the stone rests—and the upper bed, the surface in which the next above it will be placed.

The terms *superior* and *inferior*, when thus used in building, etc., refer to *situation*, not *quality*. Thus the *superior* course means the *higher*, and similarly, *inferior* means the *lower*.

In every course of ashlar facing, with brick or rubble backing, *thorough-stones*, as they are technically termed, should be introduced; their number should be proportioned to the length of the course, and every such stone of a superior course should fall in the middle of two similar stones in the course below. This disposition of bonds should be strictly attended to in long courses.

Thorough-stones or *bond-stones* are stones placed with their greatest length going *through* the thickness of the wall at the right angle to its surface. Some of the ashlar stones must be thus used, or the facing, having nothing to connect it with the backing, would soon separate itself from it and give way. Bond-stones are generally put in alternate courses with backing to the jambs of windows, doors, etc. They are placed alternately in the different courses, so that they may not come immediately over each other, and thus the tying is spread over the whole surface of the wall; but unless the backing be set in quick-setting cement, or otherwise carefully packed, the tendency of the backing to settle away from the facing will not be counteracted.

In every pier where the jambs are coursed with the ashlar in front, every alternate jamb-stone ought to go through the wall with its beds perfectly level. If the jamb-stones are of one entire height, as is frequently the case when architraves are wrought upon them and upon the lintel crowning them, every alternate stone at the ends of the courses of the pier which are to adjoin the architrave jamb ought to be a "thorough-stone;" and if the piers between the apertures be very narrow, no other bond-stone will be necessary in such short courses; but where the piers are wide, the number of bond-stones must be proportioned to the space. Thorough-stones must be particularly attended to in the long courses, below and above the windows.

The term *architrave* is applied to the assemblage of members or mouldings which surround a door or window, the sides of which are called *jambs*, and the cross-top the *lintel* or *traverse*. The under side of the lintel—that is, the *ceiling* of the opening, or the surface seen on looking upward when standing in a doorway—is called the *soffit*.

Bond-stones should have their sides parallel, and of course at right angles to each other, and their horizontal dimensions in the face of the work should never be less than the vertical one. All the vertical joints, after receding about three-quarters of an inch from the face with a close joint, should widen gradually to the back, and thereby form wedge-like hollows for the reception of mortar and packing. The adjoining stones should have their beds and vertical joints filled with oil-putty from the face to about three-quarters of an inch inwards, and the remaining part of the beds with well-prepared mortar.

Putty cement will stand longer than most stones, and will even remain permanent when the stone itself is in a state of dilapidation from the corroding power of the atmosphere.

It is true that in all newly-built walls cemented with oil-putty, the first appearance of the ashlar work is somewhat unsightly, owing to the oil of the putty spreading into the adjoining stones, which makes the joints appear rather dirty and irregular; but if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly appear, and the whole work will seem as if one piece. This is the practice in Glasgow, but in London and Edinburgh fine water-putty is principally used.

All ashlars should be laid on their natural beds; that is, *the surface which was horizontal when the stone lay in its native quarry should be placed horizontally in the wall.* To understand this very clearly, the student must be informed that there are two kinds of stone known to geologists, viz., igneous (from the Latin *ignis*, fire), and aqueous (from the Latin *aqua*, water).

The *igneous* are such as have been formed by the agency of fire, which has melted some of their constituent parts and left others hard and bright. The whole of the mass, when hardened, becomes of the same structure throughout, and forms the various sorts of granite used in building.

The *aqueous* are such as have been formed by the numerous rocky particles which have been carried along and deposited by water in past ages. This sediment having become hardened by time and heat, now constitutes most of the stones we use in building, which are sometimes, from their origin, called *sedimentary*.*

Now the solid masses we know as stone have not been formed by the sediment which was deposited at one period; but ages may have elapsed between each formation: thus the stone is deposited in layers called strata (from the Latin word *stratum*, strewn or spread out), and this is the reason that such stone may be easily split into slabs, whilst granite would only chip into irregularly-shaped pieces.

This explanation will now enable the student to understand the rule that "all ashlars should be laid on their natural beds," that is, that they should be placed so that the strata of which they are formed should be horizontal, or nearly so, as they were in the quarry from which they were taken. The purpose will be clear to any reflective mind, for it will at once be understood that the strata, when standing on edge, will be more liable to separate as the stone yields to time, the influence of the atmosphere, or to pressure, and thus flakes or layers will separate vertically and drop off, leaving a portion of the stone above unsupported.

The causes of durability of stone, and the correspondent causes of failure and decay, are either chemical or mechanical, and may be described either as decomposition or disintegration. Durability also depends much on the power of resistance to wear. Decomposition is caused by some of the elements of the stone entering into such new combinations with water, gases, or acids, as render them soluble either by air or water. Thus granite, though the hardest of building stones, is liable to serious decomposition when the feldspars are alkaline, and will unite with water or acids. Some qualities of this stone are rapidly decomposed by the sea, and various causes of a similar character affect other stones, the consideration of which would carry us beyond our present subject.

Disintegration is the separation of parts of the stone by mechanical action. One of the chief causes is the freezing of minute drops of water which get into the pores or fissures of the stone, swell slowly as crystals of ice are gradually formed, and consequently burst open the pores or split the grain of the stone; and thus, as said before, if the stones be face-bedded, the laminæ, or thin leaves of which the aqueous or stratified rocks are composed, scale off one after another, just as leaves of a book turn over when it is placed on its back.

Resistance to wear is another obvious cause of durability; but this depends rather on the toughness than the mere hardness of the material (a quality often attended with brittleness), as also on its situation. The crushing weight of Portland stone is about 10,000, while that of York is about 12,000, or one-fifth more; but in many situations Portland steps will last much longer than York. Again, the crushing weight of Peterhead granite is about 18,000, or not quite double that of Portland, whereas, if used as street-paving, it would outlast six sets of the latter.

As many of the principles of building in stone apply equally to brickwork, they will be found under that head, and masonry will be further considered in a section devoted to drawing as applied to stonework.

NOTABLE INVENTIONS AND INVENTORS.

II.—GAS-LIGHTING.

BY JOHN TIMBS.

THAT the existence and inflammability of coal-gas should have been known in Europe more than a century and a half before its application to economic purposes is a striking instance in the history of great discoveries. The Chinese, however, are stated to have employed, for ages, spontaneous jets of gas—derived from boring into coal-beds—for illumination and other economical purposes. This inflammable gas is described as forced up in jets, and conveyed through tubes, for lighting streets, apartments, and kitchens, as well as "portable gas" in

* For further information on the formation of stone and much other elementary but useful instruction on subjects connected with building, tools, etc., the student is referred to "Our Houses" (Cassell's Primary Series).

bamboo canes; and in the village of Fredonia, in the United States, such gas has very long been used both for cooking and illumination.

In England the application dates from the year 1659, when Thomas Shirley correctly attributed the exhalations from the burning well of Wigan, in Lancashire, to the coal-beds which lie under that part of the county; and soon after, the Rev. Dr. John Clayton, influenced by the reasoning of Shirley, actually made coal-gas, and described the results of his labours to the Hon. Robert Boyle, the eminent chemist, who died in 1691. He says he distilled coal in a close vessel and obtained abundance of gas, which he collected in bladders, and afterwards burnt for the amusement of his friends, the gas coming from the bladder through holes made in it with a pin. This was a hint which, in an age more alive to economise improvement, might have brought gas-lighting into operation a century earlier, though the mechanical difficulties might have been too great to overcome at that period. In the year 1753 Sir James Lowther described to the Royal Society a spontaneous evolution of gas at a colliery near Whitehaven. It annoyed the workmen so much, that a tube was made to carry it off, and persons were in the habit of filling bladders with the gas and burning it at their convenience. It appears still more strange that this hint did not bring gas into use earlier. A tube was made to carry it off, and it burnt two years and nine months without sign of decrease; it probably diminished as the coal-bed was exhausted.

This discovery was not published in the "Philosophical Transactions" till 1739. Hughes, in his "Treatise on Gas Works," 1853, says, "To the celebrated Dr. Watson, Bishop of Llandaff, we are indebted for the first notice of the important fact, that coal-gas retains its inflammability after passing through water, into which it was allowed to descend through curved tubes;" but there is evidence in the "Miscellanea Curiosa," 1705, vol. iii., p. 201, to show that Dr. Clayton also discovered that gas retains its inflammability after passing through water.

Soon after this, Dr. Watson made many experiments on coal-gas: he distilled the coal, passed the gas through water, and conveyed it through pipes from one place to another, yet it was not introduced into general use; for although the properties of coal-gas were known to so many persons, no one thought of applying it to a useful object, until Mr. Murdoch, the engineer, at Cornwall, in 1792, erected a small gas-holder and apparatus, which produced gas enough to light his own house and offices, and he subsequently erected a similar apparatus at Ayrshire. In the following year he put up works for lighting the Soho Foundry, at Birmingham, with apparatus for the purification of the gas; this light was exhibited complete at the Soho manufactory at the Peace rejoicings in 1802; and upon a similar occasion in 1814 gas was employed to light the pagoda and bridge across the canal in St. James's Park. In 1806 Mr. Clegg exhibited gas lights in front of his manufactory at Birmingham. Halifax and other towns followed. A single mill at Manchester used above 900 burners and several miles of pipe-supply, for the erection of which, in 1808, Mr. Murdoch received the Gold Medal of the Royal Society.

With respect to the tardy progress of gas-lighting, it must not be forgotten that many interesting facts have been adduced to show that the tracks of purely scientific research, and of the subsequent applications to art, have lain very much with different parties. It was not, for example, the chemist who first showed a jet of coal-gas burning in his laboratory, who also first conceived and accomplished the noble feat of lighting up with gas a whole city, so as to make night there almost as light as day.

From the lighting of the Soho Foundry, in 1802, to the close of 1822, Sir William Congreve reported the capital invested in the gas works of the metropolis alone to be one million sterling, while the pipes extended upwards of 150 miles. Still, the light of gas was poor and its smell offensive. Lectures and experiments were next made by a German, named Winsor, who, in 1803-4, lighted the old Lyceum Theatre in the Strand; in the latter year he patented his method, and established a company which subscribed £50,000, expended in experiments, among which was the important process of purifying gas by lime. In 1807 Winsor lighted up the space between Pall Mall and St. James's Park. Two years later he applied to Parliament for a charter, when the testimony of Accum, the chemist, was bitterly ridiculed by the Parliamentary Committee. In 1814 Westminster Bridge was lighted with gas, and on Christmas Day, 1814, commenced the general gas-lighting of London. On Lord Mayor's Day, in the next year, Guildhall was, for the first time, lighted with gas.

In 1814 an explosion occurred at the gas works just established at Westminster, upon which a committee of the Royal Society reported that gas works ought to be placed at a considerable distance from all buildings; and that the reservoirs or gas-holders should be small, and separated from each other by mounds of earth or strong parting-walls. Dr. Arnott significantly records that "such scientific men as Davy, Wollaston, and Watt, at first gave an opinion that coal-gas could never be safely applied to the purposes of street-lighting." Sir Humphry Davy, then President of the Royal Society, asked one of the inventors if it were intended to take the dome of St. Paul's for a gas-holder. (The interior was experimentally lighted with gas in 1822.) In 1825 a Government committee of scientific men reported that their occasional inspection of gas works was necessary, the frightful consequences of leakage and explosion being anticipated.

The following is a brief and general description of the process of the production and purification of coal-gas, the operation being merely a process of distillation. The apparatus consists of (1) the retorts, cylinders of iron or clay, into which the coal being quickly shovelled and the mouth closed by a lid, they are placed on the fire and heated to redness which decomposes the coal and drives forth the resulting gas; (2) the dip-pipes and condensing main, employed to conduct the gas into vessels where it is removed from the tar and other gross products; (3) the purifying apparatus for abstracting the sulphuretted hydrogen, carbonic acid, etc.; and, lastly, the gasometer with its tank, into which the gas is finally received in a purified state. This is effected by the vapours from the coal being carried away by a wide tube, which passes from the cylinder into a series of vessels, where the mixed product is cooled and loses much condensible matter. Thus partially purified, the gas still retains sulphureous and other vapours, to remove which it is subjected, in some gas works, to dilute sulphuric acid, which separates the ammonia; but it is mainly purified by passing it through a series of vessels containing quick-lime, which absorbs the remaining impurities, especially the last traces of sulphur, the presence of which, more than any other circumstance, has prevented the adoption of gas-lighting in private dwellings. Dr. Letheby says of this discovery:—"It is needless to dwell on the importance of this discovery; for it is admitted on all sides that the presence of sulphur, in an unabsorbable form, is one of the most serious objections to the employment of gas as an illuminating agent; and if, as in the present case, the sulphur can be entirely removed, without in the least degree injuring the illuminating power of the gas, it is manifest that *a new era is commenced in the history of gas illumination.* I have no hesitation in saying, from my investigations of the matter, that *this discovery* of the perfect action of lime as a purifying agent *is one of the most important of the present day*, and cannot fail to give an impetus to the manufacture of gas, by securing to the public a complete protection against the hitherto objectionable properties of it."

Here we may note, that a few years ago the refuse from coal-gas works was perfectly useless, but valuable uses have been discovered for gas liquor. From coal-tar not only now are obtained naphtha, benzole, and carbolic acid, but various brilliant dyes and colours.

Under the water-tank, in which the gasometer floats, the gas is introduced, whence it is driven by the weight of the gasometer through cast-iron mains under the streets, and from them, by wrought-iron service pipes, to the burners, the supply being regulated by gauges and valves. Professor Frankland has lucidly explained, at the Royal Institution, the apparatus and processes used in the manufacture, purification, and distribution of coal-gas, by miniature gas works in actual operation. From retorts in a small furnace the products of destructive distillation are successively conveyed through stand-pipes, the hydraulic main, the water and tar well, the condenser, the exhauster, the purifiers, the station-meter, and finally the gasometer, with its governor to regulate the pressure upon the purified gas.

Professor Frankland in estimating the real source of light in coal-gas, refers it to ignited hydro-carbon gases and vapours. These gradually lose hydrogen when exposed to heat, and their

carbon particles shrink together and form compounds of greater complexity, being some of the dense vapours which exist in a gas-flame; and even the soot produced by a gas-flame is not pure, but requires intense and prolonged ignition to free it from hydrogen. A gas-flame is also perfectly transparent, and gives equal light in different positions. In the comparison of light of equal intensity, obtained from different materials, it is found that coal-gas, and especially gas from cannel coal, is the least unhealthy of all ordinary lights, which is contrary to the usual opinion.

The illuminating power of coal-gas has been greatly improved of late years, but the inquiry is too extensive for our limits. We must be content to mention the passing of gas over naphthaline, when it takes up its vapour, thirty grains of which to one foot of gas increases the light seven or eight times; with oil the result exceeds from four to five times, but even this is an important gain.

Gas has been made from oil and resin, but both are too costly for street-lighting. Wood and peat are also used, and a village in Ireland has been lighted with gas made from bog-turf. The lime-ball and the electric lights are costly. The Bude light was first used for lighting the House of Commons in the year 1812; its flame, acted upon by a current of oxygen, has its brilliancy increased by a current of atmospheric air.

It has been calculated that an ordinary candle consumes as much air while burning as a man does in the act of breathing; the same may be said with regard to gas, oil-lamps, etc., bearing a proportion to the amount of light evolved. One hour after the gas of London is lighted, the air is deoxidised as much as if 500,000 people had been added to the population. During the combustion of oil, tallow, gas, etc., water is produced. In cold weather we see it condensed on the windows of ill-ventilated shops. By the burning of gas in London during twenty-four hours, more water is produced than would supply a ship laden with emigrants on a voyage from London to Adelaide.

Dr. Johnson is said to have had a prevision of gas lighting streets, when one evening, from the window of his house in Bolt Court, he observed the parish lamp-lighter ascend a ladder to light one of the glimmering oil-lamps; he had scarcely descended the ladder half way when the flame expired; quickly returning, he lifted the cover partially, and thrusting the end of his torch beneath it, the flame was instantly communicated to the wick by the thick vapour which had issued from it. "Ah!" exclaimed the doctor, "one of these days the streets of London will be *lighted by smoke!*"

PROJECTION.—VI.

THE PROJECTION OF CYLINDERS

A CYLINDER is a solid body of the character of a prism, but its *ends* are *circles*. The axis, or line on which a cylinder might be turned, unites the centres of the ends; and if the ends are at right angles to the axis, the solid is called a *right* cylinder. If the ends are inclined to the axis, so that if the cylinder were placed on one of them it would be slanting instead of upright, it is called an *oblique* cylinder. In the first case the ends would be circles; but in the second, although all the sections at right angles to the axis are circles, the ends being at an angle to it are ellipses. It will be readily understood that all sections passing from one end of a cylinder to the other, *parallel to the axis*, will be parallelograms; and by rolling up a rectangular piece of paper it will be seen that the surface of development of a cylinder is a parallelogram, the height of which is equal to the length of the cylinder, and the breadth to its circumference.

Fig. 79 is the plan and elevation of a cylinder when standing on its base, and it will be evident that then, although the cylinder might be rotated on its axis, that axis would remain at right angles to the horizontal, and parallel to the vertical plane.

Fig. 80 shows the elevation of the cylinder when its axis is at 45° to the horizontal, and parallel to the vertical plane.

To project the plan of this, on A B describe a semicircle which will represent half of the end. Divide this semicircle into any number of equal parts, C D, D E, etc., as in Fig. 77 in the last lesson. From the points C, D, E, etc., draw lines parallel to the axis of the cylinder, which, passing from end to end, will give the same points in both. Draw a line for the axis of the plan parallel to the intersecting line, and perpendiculars from the various points in the elevation. Mark off the lengths, *c c*, etc., on each side of the axis, and through the points thus obtained draw the ellipses forming the plans of the ends. Unite these by lines parallel to the axis, which will complete the plan.

Fig. 81 is the projection of the cylinder when the axis is at 45° to both of the planes of projection. No description of the working is deemed necessary, as it is simply a repetition of Fig. 78 in the last lesson, and will, no doubt, be readily understood.

On referring to Figs. 27, 28, 29, 30, the student will be reminded that if a solid be cut across the parts will, when rotated on a centre, form an "elbow"—that is, they may be joined so as to turn a corner. This principle holds equally good in relation to cylinders.

Fig. 82 is the plan and elevation of a cylinder which it is required to cut so that the parts may be joined to form an angle of 90°. The following rule must be impressed on the minds of students, viz.: Whatever may be the required angle, the section must be made at *half* that angle with the axis. Thus, if a pipe is to follow two walls which meet at an angle of 120°, each part must be cut at 60°; and, therefore, in the present figure, draw the section-line, A B, at 45° (half of 90° required). If now the upper part of the cylinder be rotated on a centre (C), the point B will meet A, and the line B F will become A G. Now divide the plan into any number of equal parts at E, D, etc., and carry up perpendiculars from these points to cut the section-line in *d′*, *d′*, *e′*, *e′*.

To find the true section, draw A B (Fig. 83), equal to the section-line A B in Fig. 82, and set off on this line all the distances, A *e′*, *e′ d*, etc. Through the points *e′*, *d′*, etc., draw lines at right angles to A B, and set off on them, on each side of the line A B, the distances which the points similarly lettered are from the central line A B in the plan, thus obtaining the points C, *c*, D, *d*, E, *e*. Draw the curve of the ellipse, which forms the true section, through these points.

Fig. 84.—To develop this cylinder, draw a horizontal line and a perpendicular, A. On each side of A set off the six equal spaces into which the two parts of the plan in Fig. 82 are divided, viz., A E, E D, etc., and A *e*, *e d*, etc., placing the letters E, D, etc., *e*, *d*, etc., in the order in which they follow on each side of A. Erect perpendiculars from each of these points, making B F equal to the height of the original cylinder (Fig. 82). Join F F, and the parallelogram B F F B will be the development of the entire cylinder.

To trace the section-line on this development—that is, *to draw the line in which the material is to be cut so as to form both the parts of the cylinder*—erect perpendiculars from each of the points between B, B, and make them the height of those similarly lettered in the elevation. This is best done by drawing horizontals from the points in the section-line to cut the perpendiculars in the development which are similarly lettered. The points A, *e*, *e*, *d*, *d*, *c*, *c*, *d*, *d*, *e*, *e*, B, B, will be thus obtained; and through these the curve is to be traced, which will be the development of the line of section; and if a piece of sheet iron, or any other material, were so cut, the parts when rolled and joined will give exactly the same figures, the joint or seam being at the highest point in the one, and at the lowest in the other part.

Fig. 85 is a view of the lower portion projected from the plan, when the diameter, A B, is at an angle instead of being parallel to the vertical plane.

Fig. 86 shows the elevation and half-plan of a cylinder, which, on being cut twice at 45°, may be converted into a "double-elbow."

Having drawn the half-plan (only the half is required, as the points in the other half would be immediately at the back of those here given), project the elevation from it; then divide the semicircle into any number of equal parts, and from these points of division draw perpendiculars. Next draw the section-lines at the required angle (in this case 45°), and at the two extremities of the lower one draw lines at right angles to the elevation of the cylinder; make these lines equal in length to the middle portion of the cylinder, and join them by a line at 45°. Erect perpendiculars at their extremities equal respectively to the corresponding lines in the lower portion of the object. Join these by a horizontal line, and this will complete the elevation.

The development of the piece of metal of which this double-elbow is to be cut must now receive our attention. Produce the base-line of the cylinder, and at any part of it erect a perpendicular (Fig. 87), from which set off on each side the same number of equal parts as that into which the half-plan of the cylinder is divided, and draw perpendiculars from the points. From the top of the original *erect* cylinder draw a horizontal line,

Fig. 79.

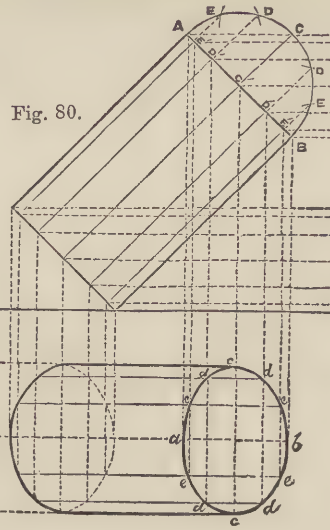

Fig. 80.

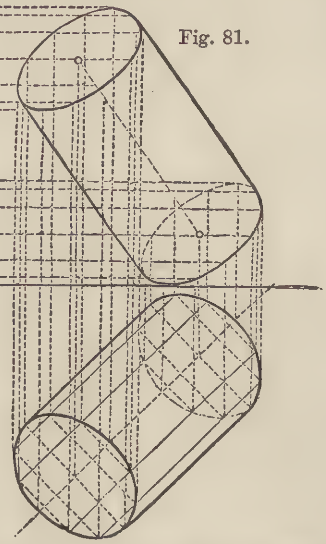

Fig. 81.

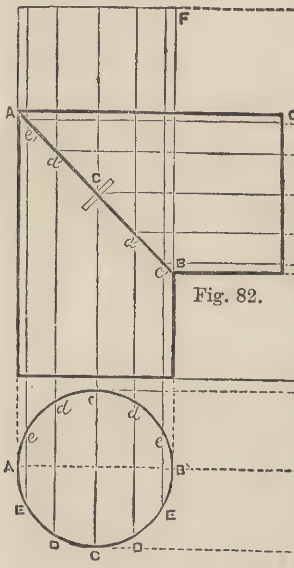

Fig. 82.

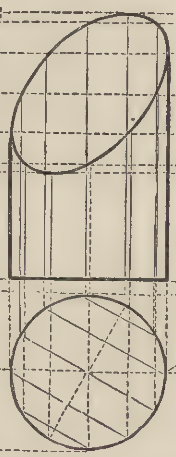

Fig. 85.

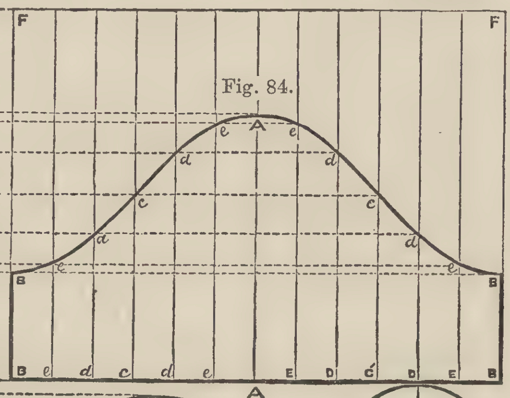

Fig. 84.

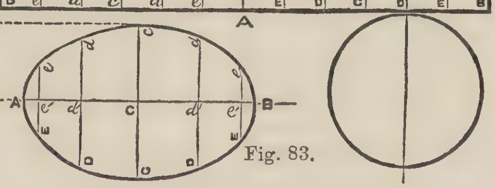

Fig. 83.

and this, uniting the two external perpendiculars, will complete the general development. Returning now to the elevation of the original cylinder, it will be seen that the perpendiculars which were drawn from the points of division in the plan, cut both of the section-lines, and from these points of intersection draw horizontal lines to cut the perpendiculars in the development, that drawn from the highest point (viz., the point where the section-line starts from the side of the elevation) to cut the *central perpendicular*, and that from each of the other points to cut the next *pair* of perpendiculars in succession; through these points the curve, which is the development of the section-line, is to be drawn. The lower section-line will, of course, be developed in precisely the same manner from the corresponding points of intersection occurring on it.

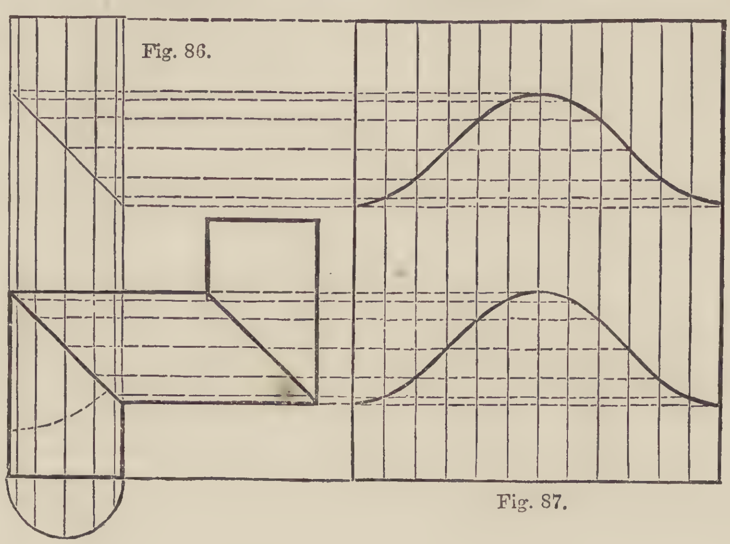

Fig. 86.

Fig. 87.

Fig. 88 is the elevation and plan of one of the ends of the

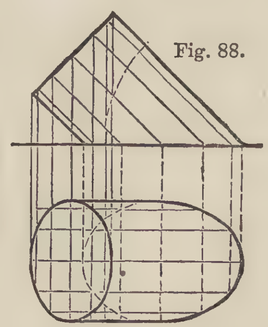

Fig. 88.

above object when resting on its section. On a horizontal line mark off the length of the *section-line in the elevation*, and at the extremities draw lines at 45°; make these equal to the length of the longer and shorter sides of one of the end pieces of the elevation, and join them by a line which will (if their lengths be correct) be at right angles to them. Divide this line into two equal parts, and from the bisecting point draw a line parallel to the sides already drawn: this will be the axis. On each side of this draw lines parallel to it, and at distances apart corresponding with those in the elevation, to meet the intersecting line. Drop perpendiculars from these intersections, passing through a horizontal line drawn in the lower plane; on these set off from the horizontal line the widths of the corresponding lines in the plan; join the extremities by tracing an ellipse to touch each, and this will be the true section on which the object now rests. From each of the points through which the ellipse has been traced draw horizontal lines, and intersect these by perpendiculars drawn from the points occurring in the *end* of the object; through these intersections draw the ellipse, which will be the plan of the end.

TECHNICAL EDUCATION ON THE CONTINENT.—IV.

BY ELLIS A. DAVIDSON.

POLYTECHNIC SCHOOL IN HANOVER—THE DIRECTION.

The management of the general affairs of the school is vested by the Royal Commission in (1) the Director, and (2) the Principal (syndicus).

The Director, whilst virtually responsible for the conduct of the whole Institution, takes especial charge of the monetary department and accounts; he also supervises the collections of models, specimens, etc., which are entrusted to the teachers of the different departments. The library is under his direct care; he exercises a general supervision over all persons employed in the establishment, and regulates the discipline of the students.

The Principal holds his office under the general superintendence of the Director, his duties relating more to the internal management of the institution. Thus amongst them are comprised—

1. The receiving and enrolling of pupils and attendants at lectures, in connection with the Director.
2. The conduct of the School Register in all the departments of the establishment.
3. Correspondence with parents of pupils, etc.
4. The receiving of returns from the teaching and domestic staffs, the compilation of reports, etc., in relation to students, lectures, teachers, and household matters.

GENERAL MANAGEMENT OF THE INSTITUTION.

The general conduct of the institution is vested in—

1. A selection from the body of teachers and professors associated with the Director.
2. A sub-committee for all matters affecting the discipline of the establishment, consisting of five members of the general teaching staff and Board of Management, together with the Principal of the Polytechnic School.
3. The general board, called the "Plenum."

The duties of the body named in Section 1 constitute them what may be properly called the working school board. They administer the laws and regulations, decide on all cases which may arise, and legislate for all circumstances occurring which are not provided for by existing laws; they prepare the course of studies, attend to matters of general discipline, and re-organise and modify arrangements in the internal working of the school, according to the requirements of the period. This body also decides on the applications for admission as free students and exhibitioners; they confer with the Director, and make such suggestions as to alterations, etc., as their experience of the practical working of the school may from time to time show them to be necessary.

The general board, or "Plenum," is composed of the entire body of professors and teachers, and in its meetings the Principal of the school presides. The duty of this body at their conferences is (1), so to regulate the scholastic matters that all the teachers may work harmoniously, and that the classes may be so arranged as to assist, instead of obstructing, each other. (2) To receive the income and regulate the expenditure thereof in conjunction with the Director. (3) To select the students for premiums and other rewards. (4) To select the in-coming students from the gross number of applicants, according to the result of a preliminary examination. (5) To select the sub-committee for discipline alluded to above.

THE SCHOOL.

The school is divided into Upper and Lower.

The students of the Lower School are, as a body, required to take all the subjects prescribed. This regulation is only relaxed in exceptional cases, such as (1) where an independent student (that is, one who is his own master) wishes to attend certain of the classes; (2) where a student in the Upper School, who may be backward in any individual subject, desires to receive further elementary instruction not given in the Upper School. All are admitted to the freehand and linear drawing classes without reference to attendance for other subjects.

The students of the Upper School are free to attend such lectures as they may find adapted to the course they are pursuing; this permission being subject to the capacities of the class-rooms.

The students are, however, required to attend the classes and lectures belonging to their course with the utmost regularity and punctuality; to prepare their studies, designs, and general work with the greatest care and diligence; and to obey in every respect the code of rules, a copy of which is handed to them on their admission.

Respectable persons who are above twenty-one years of age, or who have studied in one of the universities, are admitted to the school as "auditors" (zuhörer).

ENTRANCE TO THE SCHOOLS.

Candidates for admission to the Lower School must be at least sixteen years, and to the Upper School at least seventeen years of age. They must present testimonials as to conduct and acquirements, and must be prepared to submit to the preliminary examination as under:—

(*a.*) German language, style, and idiom; an essay to be written on a given theme, which shall be correct in composition, grammar, and orthography, and which shall show an acquaintance with, and an intellectual method of treating the subject.

(*b.*) Facility in arithmetic, including decimals.

(*c.*) An acquaintance with the elements of algebra.

(*d.*) A knowledge of plane geometry.

(*e.*) A general knowledge of geography and history.

The preliminary examination for admission to the Upper School is based upon the course of studies in the Lower School, since the one serves as a stepping-stone to the other.

Students who enter the Upper School expressly for the study of natural history are not compelled to take the mathematical examination; they must, however, give proof that they possess sufficient education to enable them to understand the lectures and to work them out. Students of freehand drawing or modelling are not required to undergo any educational test, and are admitted at sixteen years of age.

Having thus given the history, constitution, and system of management of this noble institution, we can now proceed to consider the courses of study pursued in the school.

We cannot, however, in reviewing the constitution of the governing bodies, avoid being struck by the circumstance that the *professors* and *teachers* are those who regulate the whole. Does not this in some degree account for the great measure of success which has been achieved by this school and others on the Continent of a similar character? In England our managing committees are elected by their social and pecuniary position, not by their educational status; it is not admitted that the *masters* are really the *school*, but they hold merely the position of journeymen who do a given amount of labour for a given wage; and since the latter is, as a rule, far below what ought to be paid to gentlemen of education and position, the quality of the former is in many cases of a secondary character, or is very grudgingly given.

COURSE OF STUDY IN THE LOWER SCHOOL.

1. *Lower Mathematics.* (First course, five hours weekly.)

Arithmetic: powers—the binomial theorem—the theory of numbers—decimal and vulgar fractions—evolution—equations

of second, third, and fourth degrees—imaginary quantities—logarithms—simple and compound interest—stocks, etc.

(Second course, five hours weekly.)

Plane geometry—similar figures—measurement of surfaces—regular polygons and circles—plane trigonometry—stereotomy—the relations of the vertical to the horizontal, and of plane to plane—solid angles and spherical triangles—determining the volume and development of solids bounded by planes—cylinders—cones and spheres.

This syllabus may at first sight appear rather high; but it must be borne in mind that the students are all above sixteen years of age, and that they have all attended schools of a class which will be hereafter described; in these the steps of instruction have been such as to lead up to the course of study as carried on in the Polytechnic School.

2. *Zoology and Botany.* (Five hours per week.)

Zoology in winter, botany in summer: general classification of animals and plants, with special reference to the animal and vegetable products used in trade. Practical study from natural objects, and modelled imitations of them, is combined with the lectures. In addition to this there is a class for the practice of microscopic investigation, and also in the summer excursions for the collection and examination of living specimens.

3. *Mineralogy.* (Five hours per week.)

The elements of geology, mineralogy, and crystallography, by lessons, lectures, and practical observation.

4. *Freehand Drawing.* (In three divisions—lower, middle, and upper. Ten hours per week.)

Ornamental drawing from flat examples and casts—in the upper divisions from casts of heads, figures, etc.

5. *Linear Drawing.*

The elements of projection—geometrical constructions as studies of the combinations of straight and curved lines—linear drawing from copies. It may here be pointed out, that students who pass from the Lower to the Upper School, and intend devoting themselves to the study of either architecture or engineering, must show that they have advanced in freehand and linear drawing, at least as far as the middle division.

COURSE OF STUDIES IN THE UPPER SCHOOL.

1. *Higher Mathematics.* (First course, five hours per week.)

Analytical plane geometry—differential calculus—differentiation and continued differentiation of the explicit and implicit functions of one or several variables — Taylor's theorem—maxima and minima—the apparently indeterminate forms, $\frac{0}{0}$ etc.—integral calculus.

2. *Higher Mathematics.* (Second course, four hours weekly.)

Spherical trigonometry—analytical geometry of surfaces—double and multiplied integrals—general and partial differential equations—interpolations—methods of the least squares—mathematical statistics, etc.

3. *Solid Geometry.* (Six hours weekly.)

Orthographic projection of a point—line and plane—sections and developments—the projection of shadows—perspective, etc.

4. *Practical Geometry.* (First course.)

(Lectures, three hours per week; plan drawing and surveying, four hours per week in the summer; and drawing from given measurements in the winter.)

Fundamental principles of practical geometry and its object—description, construction, and practical use of the instruments used in measuring, surveying, and levelling, map-drawing and measuring heights—the surveyor's table—levelling-pole, chain, theodolite, etc. Students, before entering upon this course, are required to show their previous knowledge of the subject as far as taught in the Lower School, and are also expected to be acquainted with the elementary principles of physics.

5. *Practical Geometry.* (Second course.)

(Lectures, two hours weekly; plan drawing and surveying, four hours per week in the summer, and drawing from given data in the winter.)

The higher study and application of the subjects of Course 1—trigonometrical and barometrical measurements of heights—geodesy—map-drawing from actual survey.

6. *Mechanics.* (First course, five hours weekly.)

In the first ten weeks of the course, lectures are given showing the practical application of higher mathematics to the present subject.

7. *Mechanics.* (Second course, five hours weekly.)

The conditions of entering on this course are, a sound knowledge of higher mathematics, Course 2; and of mechanics, Course 1.

8. *Mechanical Construction.* (First course, lectures, five hours; study, eight hours weekly.)

(*a.*) Introduction—the component parts of machinery—nuts and screws — gibs and cottars — plummer-blocks — axles—cylinders — couplings — friction and tooth-wheels — levers—cranks—beams—direct motion — pipes — valves — glands and collars—pistons, etc.

(*b.*) Arrangements for regulating motion—fly-wheels—governors—breaks—also simple crabs, pumps, and presses.

9. *Mechanical Construction.* (Second course.)

(*c.*) Continuation—crabs and cranes—the construction of water-wheels — turbines, steam-engines — pumps and blowing engines—railway machinery, with especial reference to the construction of locomotive engines and railway wagons—wheel gearing—kinematics.

10. *Mechanism.* (First course, general consideration, five hours weekly.)

(*a.*) The popular importance of machinery — quantity, quality, and price of mechanical work, illustrated by examples—advantages and disadvantages of certain constructions—machines for measuring and counting—clockwork for measuring time and other purposes—registering machines—water and gas meters—dynamometers—weighing machines—historical review of machines for producing motion, and for changing the places or forms of bodies—classification of machines.

(*b.*) Specialties of machines for producing motion—water-wheels, vertical and horizontal—hydraulic pressure engines, for reciprocating or rotary motion—windmills—steam, caloric (including gas-power) engines—machines for moving bodies—road and railway locomotives—steamships—windlasses—cranes and other raising machines—water-raising machines and fire-engines—blast and suction machinery—machines for altering the shape of bodies, especially mills—agricultural and domestic machinery.

11. *Mechanism.* (Second course, five hours weekly.)

Recapitulation of the principles of mechanics, with special reference to the solution of problems in kinematics, and the regulating of motion in machinery—experimental hydraulics—the theory of water-wheels and of blast and suction machines—the theory of vertical and horizontal water-wheels—the theory of hydraulic pressure engines, for reciprocating or rotary motion—the theory of steam-engines, railway locomotive, and street-transport engines—the theory of the steam-ship—the paddle—screw and reaction propellers—theory of blast and suction machines—hammering, stamping, and rolling machinery.

FORTIFICATION.—II.

BY AN OFFICER OF THE ROYAL ENGINEERS.

TYPES OF FIELD PROFILES ON LEVEL GROUND—DEFINITIONS—NAMES OF SLOPES, ETC.—USES OF VARIOUS PARTS OF PROFILE—PENETRATION OF RIFLE BULLETS—PENETRATION OF ARTILLERY—NECESSITY FOR VARIETY OF PROFILE TO SUIT THE GROUND—DEFINITION OF DEFILADE—MEANS OF AFFORDING ADDITIONAL SECURITY TO MEN FIRING OVER THE PARAPET.

Types of Field Profiles.—The ordinary earthen parapet is a mound of earth thrown out from an excavation near it.

When this excavation is behind the mound it is called a *trench*, and when it is between the mound and the enemy it is called a *ditch*.

In the latter case, the defenders either fight on the same level

as their opponents, or are raised above them, and the excavation serves as an obstacle to the enemy's advance.

When (as in permanent fortification) it is possible to make the *ditch* both broad and deep, it forms a serious obstacle, and affords sufficient earth for the formation of a really important parapet (Fig. 1).

In field works, however, it rarely happens that the ditches can be made more than ten or twelve feet deep, in which case the obstacle is not sufficiently formidable, and additional arrangements must be made to delay the enemy under the close fire of the work.

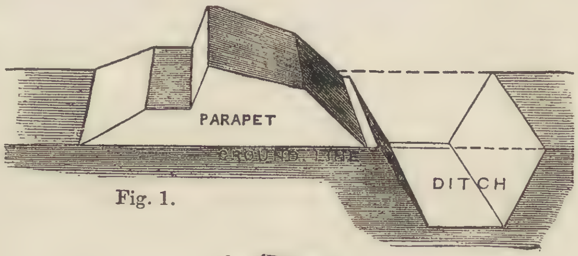

Fig. 1.

When completed with a sufficiently high parapet, this is the best formation, as it offers the advantages of a commanding position to the defenders, and protects them by an obstacle in front; it is not, however, a rapid method of obtaining cover.

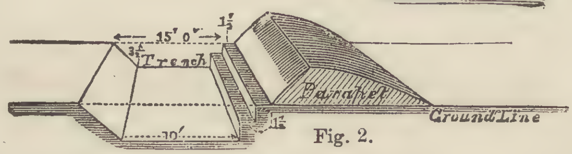

Fig. 2.

Cover is more rapidly obtained by excavating a trench, in which the defenders can stand to fire over the mound of excavated earth; because by this arrangement they are protected by the parapet as well as by the depth of the excavation. Thus, for instance, a trench three feet deep will afford about six feet of cover. The trench formation is therefore generally adopted for hasty entrenchments in the field, and for the parallels and approaches employed in sieges, to enable the besiegers to advance towards the well-armed and formidable works of a fortress (Fig. 2).

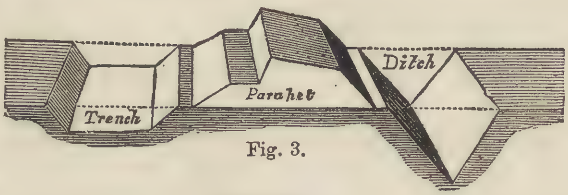

Fig. 3.

It must, however, be observed that there is no obstacle whatsoever opposed to the enemy, and that as the defenders are standing in the trench, they are lower and consequently fighting to a certain extent at a disadvantage with an enemy outside.

Fig. 4.

Occasionally, when there is plenty of labour available, but when the time for the construction of the parapet is limited, or when it is desirable to construct a thicker parapet in a given time than could have been obtained by either of the above methods, a double set of workmen are employed—one party digging a ditch and the other a trench, and throwing up the earth between them (Fig. 3).

Fig. 5.

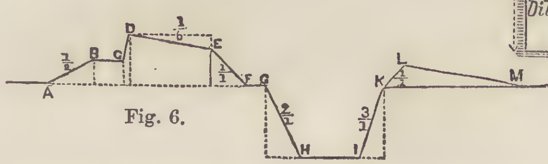

Fig. 6.

This arrangement has many advantages; it has, however, the defect belonging to all trench formations, viz., that the trenches are liable to be flooded in rainy weather, unless special arrangements are made to drain them; and that, unless the parapet is unusually high, the defenders are only under cover while standing in the trench.

It is applicable to rocky or marshy sites, where neither ditch nor trench can be made deep enough to provide sufficient earth for the parapet.

Definitions.—The following terms are frequently made use of with reference to the profiles of works, and should be understood :—

A *revetment* is an arrangement for supporting earth at a steeper slope than it would naturally assume, and various materials may be used for this purpose.

The *command* is the height of the highest point or *crest* of a work above the level of the ground on which it stands; or above some other work over which it has to fire.

The former is termed the *absolute command*, the latter the *relative command*. A work is said to have a *command of fire* over another work, when its relative command is such as will admit of a direct fire from both parapets being kept up simultaneously, without danger to the defenders of the front work.

Assuming the work to be on level ground, in the same plane with the enemy's position, and that the parapet should be capable of giving cover and protection to men of ordinary stature standing a certain distance in rear, it is evident that the crest must at least be six feet higher than the level on which they stand; and when it is remembered that the trajectory or path of the enemy's projectile is a curved line, it is plain that this height must be exceeded. A command of eight feet gives a fair amount of protection, but a greater command would, of course, be better.

The *relief* is the difference of level between the *crest of the parapet* and the *bottom of the ditch*, or the command + depth of ditch.

The *terreplein* of a work is the level surface within it on which the active operations of the defence—such as working the guns, etc.—are carried on. In field-works with a low command, the terreplein is usually the original ground-line (Fig. 4); but in permanent works, with a command of twenty or thirty feet, the terreplein is the level surface on the top of the embankment or rampart (Fig. 5).

These terms "rampart" and "parapet" are so frequently misapplied, that it would be well to note that the rampart is simply an embankment or mass of some material which raises the parapet to the required level.

Names of Slopes, etc.—The names of the various parts of a profile (Fig. 6) are—A B. Slope of the banquette. B C. Banquette. C D. Interior slope of parapet. D E. Superior slope of parapet. *d e.* Thickness of parapet. E F. Exterior slope of parapet. F G. Berm. G H. Escarp. H I. Bottom of ditch. I K. Counterscarp. K L M. Glacis. K L. Interior slope of glacis. L M. Slope of glacis.

Uses of various parts of Profile.—When the parapet is high enough to give cover to those not actually defending it, a platform or step must be made at a convenient level (usually 4 feet 6 inches) below the crest, to enable the defenders to fire over the top of the parapet, with as little exposure to themselves as possible. This step is called a *banquette;* its breadth is $4\frac{1}{2}$ feet when two ranks of men are to fire, and 3 feet when only one rank is required.

The level of the banquette is gained either by steps or by a slope of about $\frac{1}{4}$, called the *slope of the banquette*, which is a sufficiently easy incline to enable men to go up or down with ease.

To enable the men, when firing, to stand close up to the

parapet, its *interior slope* is made about $\frac{3}{1}$, and as ordinary loose earth will not stand at so steep an angle for any length of time, it is supported by a revetment of sods, or some other material.

The *thickness of parapet* is the horizontal distance between the crest and the exterior slope, or, in other words, it is the base of the superior slope. It is regulated so as to exceed the penetration of the projectiles it is intended to resist.

Penetrations of Rifle Bullets.—These penetrations are very various with different guns at different ranges, and of course vary with the hardness of the resisting medium. The details of the various experiments on this subject would be too numerous to state here, and it will, perhaps, be sufficient to note some of the results. First, with reference to the penetration of the most improved specimen of small arms, viz., the Martini-Henry rifle, the following results were obtained (*vide* "Proceedings of the Artillery Institution," 1869):—

Mantlets of four thicknesses of three-inch rope were proof against bullets at 400 yards. A gabion (or cylindrical basket two feet in diameter) filled with clay *was* penetrated at twenty-five yards, but not at longer distances. Two planks of green oak were *not* penetrated at 100 yards. Twelve inches' thickness of fir planking was penetrated at 100 yards.

Earthen parapets, or sandbags filled with earth, 2 feet or 2 feet 6 inches thick, are proof against any small arms whatever.

Penetration of Artillery.—The penetrating power of artillery has increased enormously in the last few years, and the earthen parapets of field-works, which a few years ago would have been made 6 or 18 feet thick, must now (if time admits of its being done) be increased to 12 or 24 feet thick to resist field artillery; and in permanent works, to withstand the heaviest artillery, earth parapets from 45 to 50 feet thick will be required.

The top of the parapet is made to slope to the front, to admit of the musketry fire from the work sweeping the ground on the further side of the ditch. This is termed the *superior slope*, and is usually about $\frac{1}{6}$. In an earthen work it should never be made more than $\frac{1}{4}$, as if it were so, the thickness near the crest would be too weak to resist the enemy's projectiles.

The *exterior slope* is the outside portion of the parapet most exposed to fire, and consequently should be built at the inclination that the soil of which it is composed would assume when loosely thrown up.

Made-earth will rarely stand at a steeper angle than 45°, or $\frac{1}{1}$, and in sand or loose soils the angle is less; it must therefore be understood that, although the exterior slope will be assumed as $\frac{1}{1}$ for purposes of calculation, etc., it would in reality depend on the soil, and probably would be less steep than this.

Berm is a space left between the foot of a slope and the edge of the excavation near it. The berm at the foot of the exterior slope is useful, as it facilitates the repair of the parapet, and tends to prevent the weight of the parapet from breaking down the earthen slope of the escarp, and slipping into the ditch.

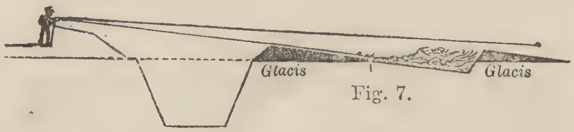

Fig. 7.

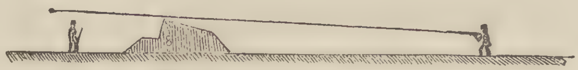
Fig. 8.

Fig. 9.


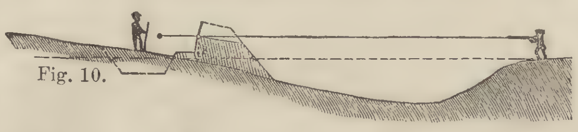
Fig. 10.

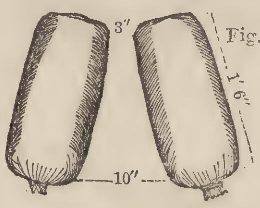

Fig. 11.

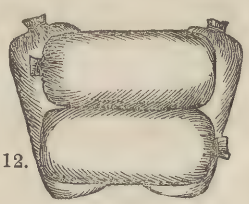
Fig. 12.


Fig. 13.

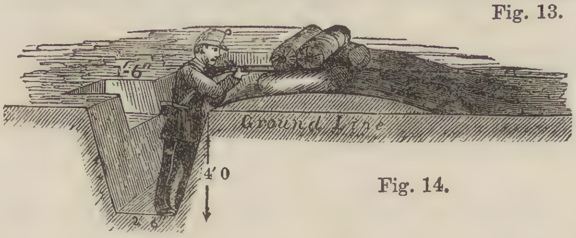

Fig. 14.

The *escarp* is the side of the ditch nearest to the work. In order to make it difficult for the enemy to get up, it would be desirable to make the escarp vertical; but the weight of the parapet prevents this being possible in field-works with unrevetted ditches. It therefore is a slope varying from $\frac{2}{1}$ to $\frac{1}{1}$, according to the tenacity of the soil.

In permanent works, the escarp is a very formidable obstacle, usually a wall about thirty feet high, placed in the ditch so as to be hidden from the distant view and fire of the enemy, and where it can only be destroyed with great difficulty.

The *ditch* provides the earth for the parapet, and, if deep enough, serves as an obstacle.

Owing to the difficulty of throwing the earth higher than twelve feet, the ditches of field-works rarely exceed that depth. In permanent fortifications, when time and labour are available, the ditches are much deeper—in some cases exceeding 50 feet in depth, as, for instance, at Portland and at Malta.

The width of the ditches in field-works is never very great, but in permanent works it varies from about 50 feet to 60 yards. N.B. The ditches of the new works at Antwerp are 60 or 80 metres in width.

The *counterscarp* is the side of the ditch opposite to the *escarp*, and as there is but little weight to bear on it, this slope in field-works may be made as steep as the soil will admit of. In a firm soil, and with moderate level strata, it will stand for some time at a slope of $\frac{3}{1}$; but all steep earthen slopes should be revetted to withstand the effects of rain and frost. In permanent fortifications the counterscarp is usually a wall which, in some cases, has a gallery behind it, and is loopholed to allow of a musketry fire being brought to bear on the bottom of the ditch.

The *glacis* is a mass of earth placed on the outer side of the ditch, to bring the ground beyond the counterscarp under the fire from the parapet; and is also used in field-works to protect, from the enemy's fire, the various obstacles intended to delay his advance (Fig. 7). The earth necessary for this latter object can be obtained by excavating, as shown above.

In all the foregoing examples it has been assumed that the works were on level ground, and that a parapet eight feet high would protect men standing in rear of it; and that men, while firing over an earthen parapet, are only protected breast high. Let us now consider how these arrangements must be modified when the ground is sloping, or the enemy is on a higher level than the interior of the work; and then how better protection can be obtained for the men firing over the parapet.

Necessity for variety of Profile to suit the Ground.—From Figs. 8, 9, 10 it will be seen that, although a height of eight

feet of parapet may be sufficient on level ground to protect men standing behind (Fig. 8), it will be necessary to obtain more cover by either raising the crest or lowering the terreplein when (as in Fig. 9) the enemy is on higher ground, or (as in Fig. 10) when the enemy is on the same level as the work, but the ground rises behind it.

Definition of Defilade.—The various practical operations that are gone through to ascertain how much the parapets should be raised to obtain cover, are called *defilade*, and will be further explained hereafter. To protect the head and shoulders of men firing over the parapet, loopholes are made on the superior slope, by laying two filled sand-bags on the slope, as shown in Fig. 11, and then laying two other filled sand-bags across them, as in Fig. 12. When sand-bags are not available, a stout log of timber may be laid lengthwise along the crest, and supported at intervals, so as to leave room underneath for men to fire between it and the crest (Fig. 13). This gives good bullet-proof cover; but if hit by a shot or splinter of a shell, the beam will probably be carried away, and may kill the men standing behind it. Fig. 14 shows a section of a rifle-pit with sand-bag loophole.

AGRICULTURAL CHEMISTRY.—III.

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CHAPTER III.—HOW PLANTS GROW.

THE final act of vegetation is the production of seed, after the performance of which function the individual plants of many species immediately perish, having in the reproduction of similar organisms accomplished their destined career. The seed developed by the mature plant contains the germ of the future individual, which may therefore be regarded as the heir to the plant; and as the provident human parent lays by a store for his offspring, intended to supply their wants until the time arrives when they shall be able to provide for themselves, so also does the parent plant ceaselessly occupy itself during a portion of its existence, in accumulating provisionary stores destined to nourish its offspring during the earlier stages of its growth. This analogy is interesting, and it admits of being further extended.

The first process which takes place when the embryo plant contained in the seed is about to assume an independent existence is termed *germination*. In order to describe this process, we must first explain the structure of the seed. We will take the common garden bean as an example. It consists of an integument, covering, or case, termed the *testa*, within which is enclosed the embryo, or immature plant. On dissecting the seed, two large oblong and flat bodies are observed, which bear some resemblance to leaves, and are termed *cotyledons*. The bean contains two of these organs, but other kinds of plants have a greater number, whilst a few species are destitute of them. On separating the cotyledons, a small bud-like projection is seen; this is called the *plumule*, and it consists of extremely minute leaves. At the base of the plumule is the *corcule*, or germ of the future plant. From the lower part of the corcule tapers an elongation, which, during the process of germination, is termed the *radicle*, and is subsequently developed into the root. The corcule is connected with the cotyledons, from which it derives its nutriment, by suitable vessels.

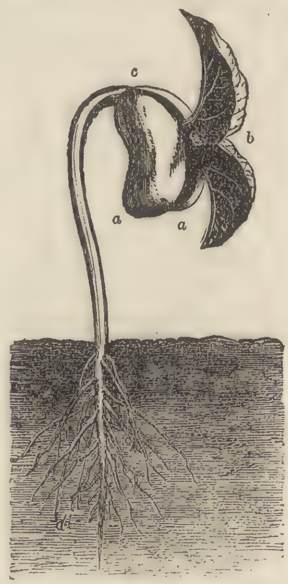
IV. GARDEN BEAN. *a.* Testa or outer covering.

When the seed is placed in the soil, and supplied with the heat and moisture necessary for germination, that process soon takes splace. The seed absorbs moisture, becomes soft, increases greatly in size, and finally bursts. The temperature at which this first effort of the vital force takes place is different in the case of different plants; for all varieties it must be above 32° Fahr. The seeds of the plants of temperate climates require, with few exceptions, a temperature of at least 40°; whilst the seeds of tropical plants do not in general germinate under 70°. According to Sachs, plants do not grow vigorously when produced from seeds which have been germinated at a low temperature; on the other hand, seeds germinated at too high a temperature do not produce healthy plants.

When the testa bursts, two shoots issue from the seed: one—the plumule—springs upwards, and is gradually developed into the stem of the plant; whilst the other, sinking into the soil, becomes in process of time the root. During these changes, the composition of the seed undergoes important alterations. Its insoluble starch is converted into soluble sugar and a gum-like substance termed *dextrine*, with which the young plant is chiefly nourished. The albuminoids, or nitrogenous matters originally present in the seed, also are employed in feeding the young plant, and they gradually disappear from the seed. The cotyledons being thus deprived of the great bulk of their starchy and albuminous constituents, sometimes perish; but very often they make their appearance over ground, acquire a green colour, and for a brief time discharge the functions of leaves.

V. GARDEN BEAN GERMINATING. *a.* Cotyledon; *b.* Plumule; *c.* Radicle.

When the cotyledons begin to act upon the atmosphere, the independent existence of the young plant commences. Up to this point oxygen gas is absorbed, and carbonic acid gas exhaled; but in future the plant will absorb carbonic acid and exhale oxygen. The great bulk of the seed is made up of starchy matter, which, being insoluble, is not capable of nourishing the plantlet. There is also present in the seed albuminoid bodies—substances containing nitrogen—which are very liable to enter into a state of fermentation. During germination a portion of the nitrogenous matter ferments, and becomes the peculiar substance termed *diastase*, which possesses the property of converting starch into sugar and dextrine. It is stated that one part of diastase is capable of converting 2,000 parts of insoluble starch into soluble dextrine and sugar. This curious attribute of diastase is common to the albuminoid bodies found in plants; they are termed *ferments*. The albuminoids are like starch, insoluble in the ungerminated seeds; but during fermentation they become more or less soluble, and thus contribute to the nutrition of the plantlet.



VI. GERMINATION OF GARDEN BEAN IN ADVANCED STAGE. *a.* Cotyledons; *b.* Plumule; *c.* Corcule; *d.* Root-fibres.

So soon as the young plant has exhausted the stores of organic food supplied by its parent, it enters upon the second stage of its existence, and now begins to *vegetate*. Henceforth it must depend upon air, soil, and water for its existence, and it must elaborate these mineral substances into the various tissues of its structure. We shall now explain the nature of the mineral food of plants, and the means by which they absorb it.

We have already stated that the great bulk of vegetable matter is composed of the elements oxygen, hydrogen, nitrogen, and carbon. These elements exist in the air—carbon as carbonic dioxide (carbonic acid, a compound of twelve parts of carbon with twenty-four parts of oxygen); hydrogen as water (hydric oxide, composed of two parts of hydrogen united with sixteen parts of oxygen); nitrogen in a free state and in the form of ammonia (a compound of fourteen parts of nitrogen and three

parts of hydrogen); and oxygen free and (combined with hydrogen and carbon) in the forms of water and carbonic acid. The greater part of the food of plants is undoubtedly supplied by the atmosphere, but it would appear that the free oxygen and nitrogen of the air are not assimilable by plants. Were the free nitrogen of the air capable of furnishing plants with the amount of this element which they require, there would be no necessity for applying ammoniacal manures to our soils. Before further considering this point, we shall state the composition of the atmosphere which surrounds our globe, extending to a height of at least forty-six miles from its surface.

AVERAGE COMPOSITION OF THE ATMOSPHERE.

		Parts.
Essential	Nitrogen	77·95
	Oxygen	20·61
	Watery vapour	1·40
	Carbonic dioxide	·04
	Ozone	traces
	Ammonia	traces
Non-Essential	Nitric acid	traces
	Carbonic oxide	traces
	Carburetted hydrogen	traces
	Sulphuretted hydrogen	traces
	Organic and solid mineral matters	traces
		100·00

According to Ville, there is but one part of ammonia in 28,000,000 parts of air; but Angus Smith found a larger proportion—one grain in 412·42 cubic feet—in the air of Manchester. Small as this proportion of atmospheric ammonia is, it appears to be sufficient for the purpose of supplying uncultivated vegetables with sufficient amounts of nitrogen. In the case of most kinds of cultivated plants, it is, however, found necessary to supplement the atmospheric ammonia with nitrogenous manures, such as Peruvian guano, ammonic sulphate (sulphate of ammonia), sodic nitrate (nitrate of soda, or cubic nitre), and the various "natural manures" obtained in the farm-yard and elsewhere. By the decay of organic matter in the soil, ammonia and nitric acid are produced, and both are sources of nitrogen to vegetation. Nitric acid is formed in the atmosphere by the oxidation of ammonia under electrical influences; and every year several pounds' weight of this substance descends upon every acre. Potassic cyanide (cyanide of potassium) is capable of yielding nitrogen to plants, as is also, as I have shown ("Transactions of the British Association, 1857"), urea, the chief nitrogenous matter in fresh liquid manure. It has been contended that the soluble organic matters in the soil directly furnish nitrogen to plants; but the weight of scientific evidence is against this assumption, as it is also opposed to the statement that vegetables are capable of assimilating the free nitrogen of the atmosphere.

The absorption of carbonic dioxide by plants takes place chiefly through the "breathing pores," or *stomata*," of their leaves. In agricultural plants the stomata are nearly altogether found on the under side of the leaves; they are very numerous, the leaves of some species of plants containing more than 150,000 per square inch of surface. The stomata communicate with the intercellular spaces in the plant, and consequently the air has ready access through them to the interior of the vegetable mechanism. It is chiefly by means of the stomata that the excessive water absorbed by the root is exhaled; and through these openings the gas generated within the plant, and not required for its nutrition, is got rid of.

Plants cannot grow in the dark. Fungi *appear* to be exceptions to this rule, but they are not in reality, for they cannot grow in the absence of light, except at the expense of the juices of other kinds of vegetables. The carbonic dioxide, water, and ammonia, taken into the vegetable mechanism, are decomposed under the stimulus of the solar beams, and their elements organised into the various structures and products of the plant. All the oxygen taken into plants in the form of carbonic dioxide is not required, and therefore a large proportion of it is exhaled through the stomata into the atmosphere. Carbonic dioxide is a poisonous gas to animals, whilst oxygen is the vital principle of the air which they breathe. Plants, therefore, by absorbing carbonic dioxide and exhaling pure oxygen, act as purifiers of the atmosphere; while, on the other hand, animals, by inspiring oxygen and expiring carbonic dioxide, indirectly contribute in an important manner to the nutrition of the vegetable creation.

The stomata have contractile powers, which subserve useful purposes. For example, under the influence of a dry atmosphere, the size of these openings decreases, and thereby prevents too rapid an exhalation of moisture from the plant. Moisture is indispensable to vegetable life; and if growing plants were deprived of all, or nearly all, the water which they contain, they would speedily perish. Under the stimulus of light the stomata increase in size, and absorb more carbonic dioxide. Plants grow, other conditions being equal, in proportion to the amount of the sun's light and heat which they receive.

The mineral or ash ingredients of plants are absorbed through the roots. Some of these ingredients—the alkaline salts for example—are soluble in pure water; others—such as, for instance, calcic phosphate—require for their solution water containing carbonic dioxide, and certain saline matters which increase the solvent power of water. The water contained in the soil holds in solution carbonic dioxide, and other matters, by means of which it is enabled to dissolve all the mineral substances required by plants. The term *spongioles* has been applied to the fine points of the branches of the root, and until recently it was the belief of vegetable physiologists that absorption of water and other matters took place only through these fibril or rootlet terminations. Ohlert, however, has shown that the real absorbing surface is close to, but not actually at, the tips of the roots. Every part of the roots, the *epidermis*, or covering of which is young, thin, and soft, appears to be more or less capable of absorbing plant-food; but they have not pores corresponding with the stomata of the leaves and stems.

The green colour of the leaves and stems of plants is due to the presence of a pigment termed *chlorophyll*. When the green colour of the leaves disappears, the growth of the plant is wholly or in part arrested, and the inorganic forces are at work. The parts of the plant engaged in the absorption of carbonic dioxide possess colour, generally green. When parts of growing plants are kept in darkened situations, the formation of chlorophyll is prevented. It is by this means that the blanching of that favourite esculent, celery, is effected.

TECHNICAL DRAWING.—VII.

WOODEN BRIDGES (*continued*).

At each end of the piers in the water, in cases where several rows of piles are driven, a sort of cutwater should be formed, in order to ward off heavy bodies, such as floating trees, ice, etc., and prevent them from injuring the superstructure (called in German constructions, "Eisbrecher," or ice-breaker). This is usually done by driving one pile by itself in advance of the rest, or by forming what is called a "dolphin" at each end of the pier.

The piers and abutments should, of course, be made in every case sufficiently strong to resist the thrust of the arch. In the case of small bridges, where the distance between the supports is sometimes as much as twenty or thirty feet, longitudinal scarfed girders may be laid upon the caps of the piles. Under such circumstances, as we have seen, there is nothing but the weight or perpendicular pressure to be provided for; and the same may be said of timber bridges of greater width for roads, and even for railways, provided the distance between the piers does not greatly exceed ten or fifteen feet. Beyond that opening, however, bridges are usually sustained by struts or tension-rods, or the roadway timbers are trussed so as to exert an oblique pressure upon the supports; indeed, in all instances of the kind, where the bays are formed upon the principle of compression or tension, the piers must be so formed as to counteract the tendency constantly exerted to force them out of their perpendicular position. This must be done either by making the piers of sufficient weight and strength to overcome any force that may be exerted against them, or else to counterbalance the efforts of one bay or arch acting in one direction, by a similarly acting arch or timber frame exerting a like amount of force in the contrary direction. The former of these methods is employed in the abutments of

a bridge, whilst the latter is invariably adopted with respect to piers.

The roadway of timber bridges is usually a flooring of boards laid upon the joists, for, in cases where sand and stones are employed, it is found that their weight, together with the humidity they engender, causes the timbers of such bridges speedily to decay. This, however, is far from being a general rule, and many splendid erections of this description are rapidly being destroyed, owing to a want of attention to this important particular. Some have proposed to cover the surface of the roadway with lead, iron, copper, etc., but the increased expense will be a great obstacle to their frequent introduction. Wood pavement forms an excellent covering for timber bridges, and is highly recommended by various engineers.

The parapet, or hand-rail, of these bridges is frequently of wood, or it may be of cast and wrought iron. Now, however,

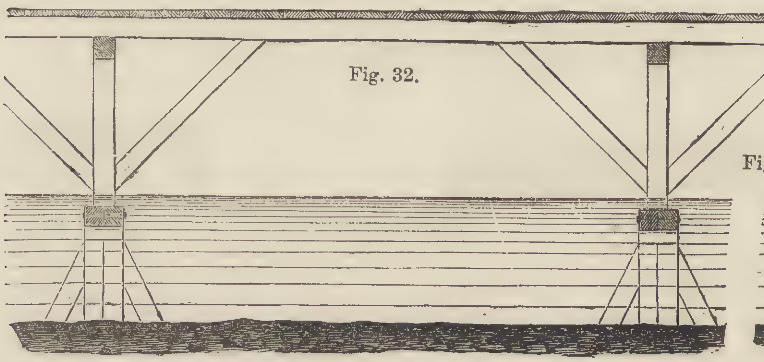


Fig. 32.

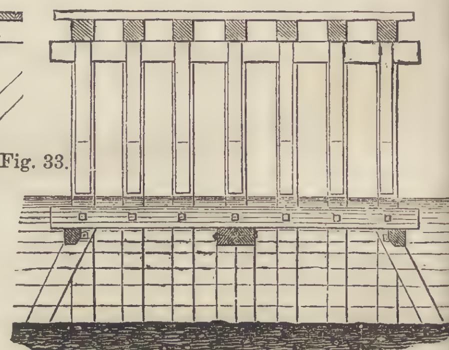


Fig. 33.

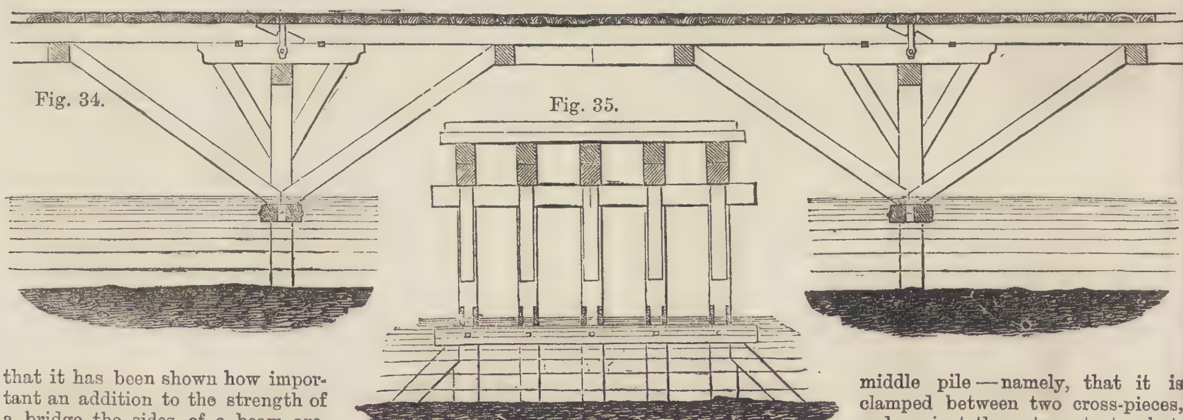


Fig. 34.
Fig. 35.

that it has been shown how important an addition to the strength of a bridge the sides of a beam are, and that it acts usefully in the direction of its depth, if it has only sufficient breadth to prevent its yielding laterally, it ought in every case to be made available to sustain the bridge, in addition to its present purposes of ornament and protection.

Fig. 32 is one of three bays of a wooden girder bridge, which is the simplest class of such constructions, consisting merely of beams laid across the stream and supported by piers formed of wooden framework, from which struts spread out on either side, which extend the bearing effect of the piers, and so diminish the length of the girder which is left unsupported.

In copying this example first draw a horizontal line, to form the top of the elevation of one of the cross-pieces, which, resting on purlins, clamp the piles forming the piers between them.

As this portion of the structure is shown on an enlarged scale in Fig. 36, the lettering here given will apply to that illustration. a' a', then, is the front elevation of the pile against which the struts, d, are firmly bolted, and on to these the purlins, f, are notched. These struts, too, are halved on to the pile at their upper ends, so that they clamp it between them. This arrangement is shown in Fig. 37, which is the side elevation.

Returning, then, to the drawing (Fig. 32), the horizontal line drawn is to be the top line of the cross-beams, which in Figs. 36 and 37 are lettered c. Now, in the front elevation these are seen in section; but, as you will require the same height in the cross-section (Fig. 33), draw this line of indefinite length at once; and this system of projecting one view from the other is to be carried on throughout, as thereby much time will be saved, and greater accuracy ensured, for it is by far easier to continue a line at once than to "piece" it afterwards.

Next draw a second horizontal line under the other, at such a distance from it as to give the lower edge of the cross-pieces, c, and then, having drawn the irregular line representing the bed of the stream, draw the vertical lines, which will form the sides of the struts, d d (seen in *front* elevation).

Now, on referring to the cross-section (Fig. 33), it will be seen that precisely this same arrangement exists in regard to the middle pile — namely, that it is clamped between two cross-pieces, and against these two struts abut. These cross-pieces are shown in section in Fig. 33, the struts being merely represented by the three perpendicular lines under these. They are, however, shown in elevation in Fig. 32, where their effect of adding to the steadiness of the frame will be evident.

The foundation of the pier being thus completed, next draw the uprights and the cross-timber resting upon them. This is shown in its full length in Fig. 33, and in section on each of the piles in Fig. 32. The upper line of this cross-timber will, of course, form the lower line of the main girders resting upon the cross-pieces. Now draw the upper edge of these girders, which, of course, are seen in elevation in Fig. 32, and are represented by seven shaded squares in Fig. 33, these squares representing the sections of the seven ribs, which will thus be seen to be made of square timber. Each of these girders rests immediately on a pile, so that the bridge is supported by seven ribs. You will now draw the struts, and as these are here placed at an angle of 45°, you can use your set-square, or, of course, you can find the exact inclination, whatever that may be, by measuring the distances of the upper and lower ends of the strut from the right angle. These struts are now to be added to the cross-section (Fig. 33), from which it will be seen that they are narrower in this direction than in the other.

The horizontal line forming the top of the flooring of the bridge is now to be drawn, and as these planks, of course, run at right angles to the girders, their ends are shown in Fig. 32, whilst their length is shown in Fig. 33.

Fig. 34 is an example of a bridge in which the struts abut against centre-pieces, placed on the under side of the girders. They do not, however, touch these centre-pieces directly, but cross-timbers, the sections of which are shown in the elevation, are placed as end-ties, and against these the struts abut.

The heads of the piles are united by a waling-piece, on which, over each pile, a saddle-piece rests, supported by struts. This gives a much broader surface on which to rest the girders, which are scarfed at this point.

In drawing this bridge, the system is precisely similar to that adopted in the former example, and therefore no further explanation need be given.

Figs. 38 and 39 are examples of scarfing the girders, and of the methods of supporting them. The latter method is that adopted in the preceding study. The subject of scarfing will be treated in "Building Construction."

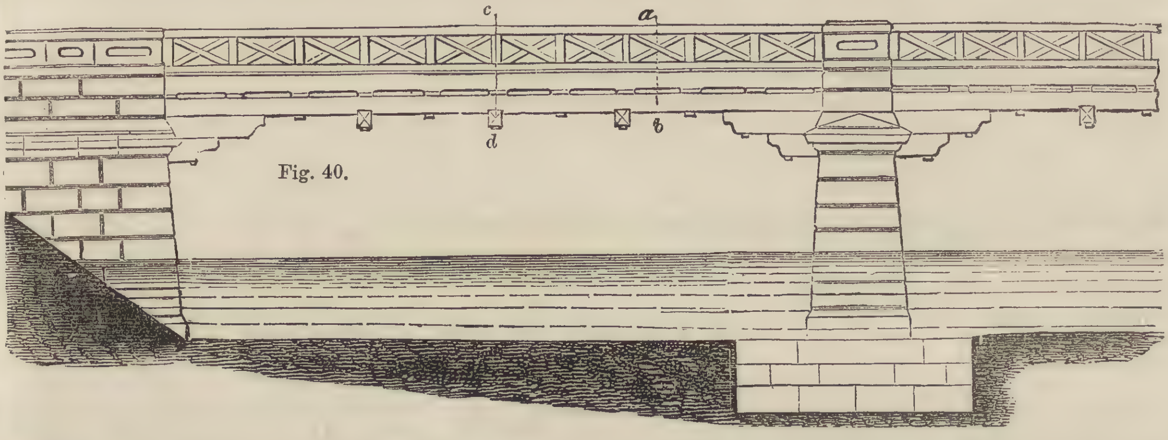


Fig. 40.

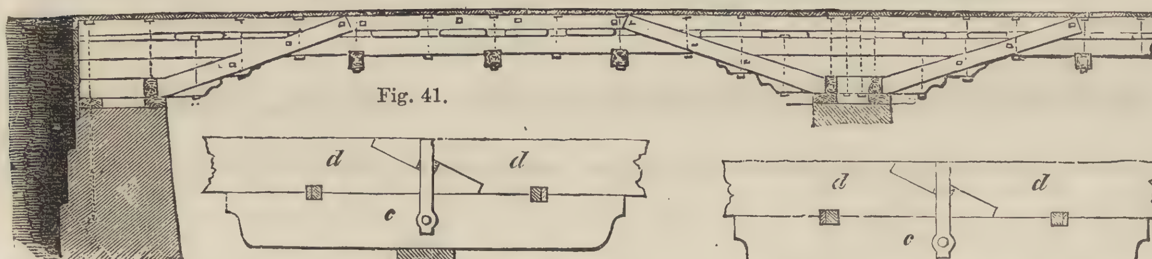


Fig. 41.

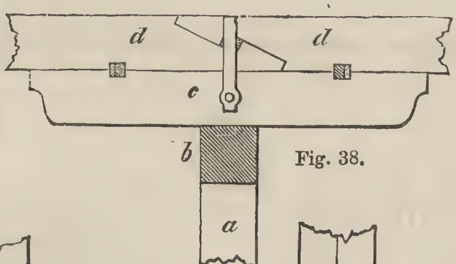


Fig. 38.

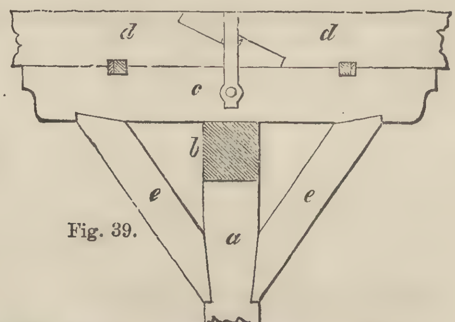


Fig. 39.

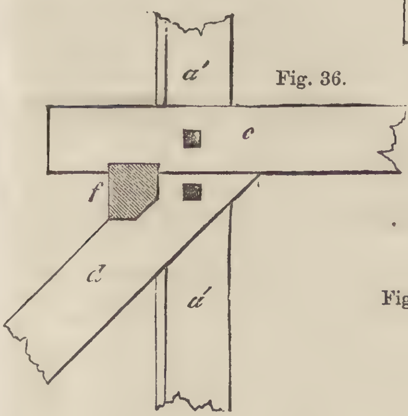


Fig. 36.

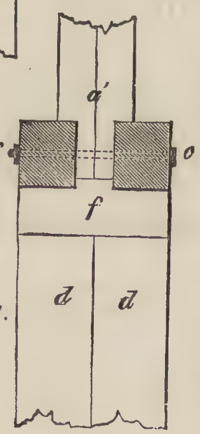


Fig. 37.

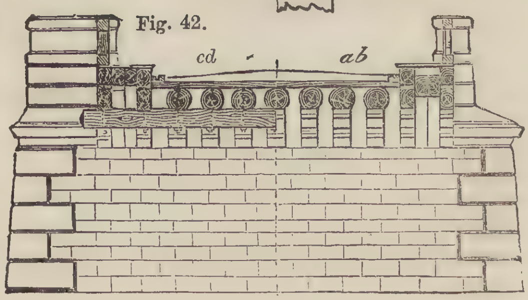


Fig. 42.

Fig. 40 is an illustration taken from a five-bay girder bridge in Germany. This is supported on stone abutments and piers, the bearing of which is extended, first, by two saddle-pieces, the upper projecting below the under one, which, in its turn, projects beyond the pier. Next, the bridge itself is formed of double girders, one above the other. Now the upper one is supported by struts, which are shown in the longitudinal section (Fig. 41), and as cross-timbers passing transversely beneath the lower girders are bolted through to the upper ones, the lower girders may be said to be suspended from those above them.

From Fig. 42, which is a transverse section on the line a b, it will be seen that the footway is raised to a higher level than the roadway by means of square timbers resting on transverse beams. The roadway is laid upon round timbers, which are extensively used in Germany.

Although only one bay is given in the example, the student is advised to draw more than this (of course to a larger scale), as the practice thus obtained will be of great service to him.

In commencing, rule a straight line for the bed of the river, and draw the foundations and embankments. Next erect per-

pendiculars on the middle of the foundations, to act as centre-lines for the piers. On these perpendiculars, mark off the heights of the cornice and capping of the piers and abutments, and draw the required horizontals; on these, mark off the respective widths from the centre-line, and complete the piers both above and below the capping.

The profile (or side view) of the abutment now requires our attention, the next task being that of drawing it at the same slant as the sides of the piers. Now, in this bridge the space between the abutment and the pier is the same as that between any two of the piers; therefore, measure that distance from *centre to centre*, and from the central perpendicular of the last pier mark off this distance on either of the horizontals, and through the point thus obtained draw a perpendicular, which will be to the profile of the abutment as the central perpendiculars are to the piers; therefore, proceed in the same manner to set off half the width of the pier on the horizontals, and thus complete the abutments.

The double saddle-pieces resting on the piers and abutments are to be drawn next, and then the double girders.

ANIMAL COMMERCIAL PRODUCTS.—IV.

RUMINANTIA (*continued*).

THE skin of the lamb is made into collars, muffs, gloves, and coat-linings. The most valued of these skins are furnished by Southern Russia, Greece, and Hungary. Beautiful black lamb-skins are imported from the Crimea, and others still more rich and glossy, with a short fur, from Astracan. The lamb-skins from Persia are known by the curl of the hair, which is produced artificially by tying up the lamb, as soon as born, in a leathern skin, and thus preventing the hair from expanding. These Persian lamb-skins are used for coats and other garments.

The skin of the fœtal calf is used for covering trunks.

The principal fur marts for the English or Canadian furs are London, in Upper Canada; Fort William, on Lake Superior; and in Lower Canada, Montreal, on the River St. Lawrence.

II.—PERFUMES.

The Musk Deer (*Moschus moschiferus*, L.; order, *Ruminantia*).—This animal, which furnishes the well-known perfume called musk, is about the size of a roebuck, without horns, legs very slender, and in all its movements exceedingly active and graceful. The musk deer is found in herds in the mountains of Central Asia, and in some of the larger islands of the Indian Ocean, such as Ceylon, Java, Sumatra, and Borneo. It is a shy animal, fond of precipices and almost inaccessible crags, and therefore very difficult to shoot. The musk is produced in a glandular pouch in the abdomen, and is peculiar to the male. It is in the form of reddish-brown coarse granules, and greasy to the touch. The average quantity which can be removed from one pouch is about 190 grains.

Musk is known in commerce under two forms—as Tonquin or Thibet musk, which is the most valuable, and Siberian, Kabardinian, or Russian musk, of inferior quality. The Oriental or Tonquin musk, from Cochin-China and Tonquin, is imported in small oblong, rectangular boxes, which are lined with lead, to prevent the escape of the odour; the musk bags, wrapped in thin blue or red paper covered with Chinese characters, are placed in these boxes. These musk bags are usually covered with hairs, which all converge towards the little narrow opening in the bag. The weight of each bag varies, some not exceeding half an ounce, whilst others weigh upwards of two ounces. Large numbers of musk deer are annually killed. The annual import of musk into the United Kingdom is upwards of 10,000 ounces.

Besides these uses, musk also possesses valuable remedial qualities. When genuine, it is one of the most powerful of the anti-spasmodics, and is applied with advantage in cases of infantile spasms, when not accompanied with inflammation.

Civet Cat (*Viverra civetta*, Gmelin; order, *Carnivora*).—A native of Northern Africa, and especially common in Abyssinia, allied to the pole-cat and marten. Body from two to three feet long, and from ten to twelve inches high; tail half as long as the body. This animal yields a perfume which is thus obtained:—The civet, when captured, is enclosed in a small cage, in which it cannot turn round, and while thus confined, the secretion is removed from its large anal pouch two or three times a week with a spoon or spatula. The interior of the pouch is glandular, the glands secreting the perfume from the blood of the animal. The substance itself is of a pale-yellow colour, and of the consistence of honey. It is not unlike musk, and to most persons smells disagreeably; but when mixed with butter, wax, lard, and alcohol, in the proportion of 1 part to 1,000, it loses its offensive character, and becomes aromatic and delicately fragrant. Thus prepared it is used in perfumery, and when employed renders more perceptible other scents with which it is mixed. Lavender and other scented waters become more agreeable by the addition of minute quantities of civet. The substance is not so much in use now as formerly; nevertheless, there is still a considerable consumption of it in this country, and as much as forty shillings an ounce is paid for it.

Viverra zibetha is another species of civet cat, peculiar to the Asiatic continent, and found from Arabia to Malabar, and in the larger islands of the Malayan Archipelago. It is much milder in its disposition than the African species, and is domesticated by the Arabs and Malays. Our supplies of civet are also derived from this animal, although to a less extent than from the African species.

Castoreum, which strongly resembles musk in its medicinal qualities and applications, is furnished by the beaver (*Castor fiber*, L.). This substance is secreted in the interior of a little bag or pouch, with which the beaver is supplied. It is brought to market, like the musk, in the pouch. The best *Castoreum* is that from Russia and Siberia; a very good quality is furnished also by Poland, Prussia, Bavaria, Germany, Sweden, and Norway; an inferior kind comes from Canada and the territories formerly belonging to the Hudson's Bay Company.

Ambergris.—This substance is obtained from the sperm whale. It is an expensive drug, because not frequently found, and is valued on account of the excellency of its fragrance. Ambergris is a morbid or diseased concretion formed in the stomach, or probably in the gall-ducts, of the sperm whale, in masses of considerable size, sometimes weighing thirty or forty pounds. It is usually found floating on the surface of the water, probably disengaged from the floating body of one of these monsters, and is rarely sought for in the intestines of the sperm whale, although it is worth a guinea an ounce. It is fished up in the Indian Ocean, near the Moluccas and Philippine Islands; also near Sumatra, Madagascar, and on the coast of Coromandel. In the Atlantic Ocean it is found near the West Indies and the Brazils. Ambergris is used as a costly frankincense, principally for perfumes, especially in France. It has also the property of increasing the power of other perfumes when mixed with them, and it is principally for this purpose that it is used.

OPTICAL INSTRUMENTS.—I.

By SAMUEL HIGHLEY.

SPECTACLES—THE NORMAL EYE.

ONE of the first offices the optician is called on to perform is to aid humanity, when through age, defect, or absolute disease, the organs of vision deviate from the very perfect optical arrangement that characterises the normal eye.

The Normal Eye.—Every perfect (or as it is technically termed, *normal*) eye possesses the power of "*accommodation*," that is, of adjusting itself for different distances, now looking at something near, as a book at reading distance, then at some far distant object, presently taking in at a glance the range of an extensive view.

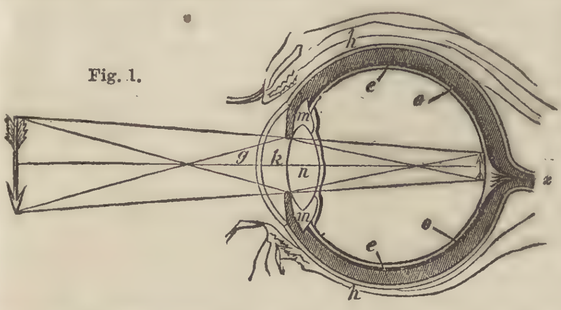
In a normal eye the whole apparatus of accommodation is so beautifully balanced, its functions performed with such ease and accuracy, that although in reality a voluntary act, its duties are from early childhood fulfilled intuitively, imperceptibly, and unconsciously.

A familiar exemplification of the power of accommodation may be made by placing one object at a yard distance from the eye, and another at six yards beyond it; on looking intently at either *we are conscious of the presence* of the other, but we do not discriminate its details; on fixing one, we lose the definition of the other. Again, if the letters of a book, held at some distance from the eye, be looked at through a gauze veil placed

nearer the eye, it will be found that when the letters are seen distinctly the veil will be seen indistinctly; and conversely, if the veil is seen distinctly, the letters will be seen indistinctly. These experiments demonstrate that images of objects at different distances from the eye cannot be defined *at the same time* upon the retina.

The human eye is a camera obscura, furnished with an achromatic lens, compounded of three principal parts, namely, the *aqueous humour*, *k* (Fig. 1), held in place by a transparent horny capsule, the *cornea*, *g*; the *crystalline lens*, *n*, the principal refracting medium; and the *vitreous humour*, *q*, which

Fig. 1.



constitutes the main body of the eye, in which optical combination the *iris*, *m*, placed between the aqueous humour and the crystalline lens, plays the part of a self-adjusting diaphragm; the circular opening or "stop" in the pupil expanding when the light is feeble or the object viewed is distant, and contracting as the light becomes more and more intense or when the object viewed is near. This compound lens projects an *inverted* image of an object on the *retina*, *o*, which corresponds to the focussing glass of the photographer's camera. The retina is a delicate and sensitive network of nervous filaments springing from the *optic nerve*, *x*, that conveys to the brain the impression of an image focussed on the retina. The *sclerotic*, *h*, a tough white membrane, forms the wall of the eye, and corresponds to the *rigid* box of a camera, and to this wall are attached the various muscles that (like the hands of the photographer) direct the eyeball to the object. The sclerotic is lined with a delicate membrane, the *choroid*, *e*, coated on its inner surface with black colouring matter (*pigmentum nigrum*), shown behind *o*, which serves the same purpose as the black paint or velvet on the inside of a camera, viz., to reduce to a minimum all internal reflections.

So far the comparison between the eye and a camera is perfect, but here the parallelism of properties ceases. In the ordinary camera the image of an object is received on a flat plate of glass; but, as a consequence of every lens being subject more or less to the defects of spherical aberration, if the central portion of the object is perfectly depicted on the screen, the marginal portion will be distorted and indistinct, through the marginal rays emanating from that object being blurred by the focal point falling short of the focussing glass; conversely, if the marginal rays are brought to focus on the screen, the central portion of the image will become indistinct through being out of focus. In the human eye, however, the retina being the most perfect form of focussing screen that could be designed—viz., hemispherical or basin-shaped—the delineating rays fall on its surface in the precise ratio of their lengths.

In the above general description of the component parts of the human eye it is stated that the external walls or sclerotic correspond to a *rigid* camera, that is to say, one wherein the box is not made with a telescopic draw, to obtain facility for focussing near and distant objects. In a telescopic camera, on pointing the lens to a near object, we have to draw the focussing glass away from the lens to secure a sharp image on the ground-glass screen (or retina of the camera), while on pointing to a distant object we must push the screen nearer the lens to obtain the same result. Now it might be supposed that the act of focussing (or power of "accommodation," as it is termed) was obtained through the elasticity of the walls of the eyeball (acted on by sympathetic muscular power), in the one case elongating, in the other contracting in length in the direction of its axis; but this is not the case. Great has been the discussion among physiologists as to the exact means by which the accommodation of the eye to far and distant objects is really effected, but general opinion at the present day is in favour of the view that it is through curvature of the crystalline lens being increased when near objects are viewed, and decreased when distant objects are observed, and further by its change of relative distance between the iris and retina.

The experiments of Dr. Young on persons deprived of the crystalline lens, and who were thereby incapacitated from focussing their sight, seemed to put the question of the power possessed by this portion of the eye beyond dispute; while the recent investigations of Cramer and Helmholtz have definitely settled it.

When the normal eye in a state of rest is adjusted for an object, D, at an *infinite distance** (at or beyond 18 feet from the eye), the rays emanating from such an object being parallel are brought to a focus on the retina (as shown at *i*, Fig. 2) without any effort of accommodation; but when an object is viewed at a *finite distance*, N (say, 12 inches from the eye), the rays emanating from such an object becoming then divergent, they will no longer be brought to a focus on the retina, but to a point behind it, as at *f* (Fig. 2), if the eye does not undergo some change which will increase its refractive power, and bring these divergent rays to a focus upon the retina. The normal eye does by its power of accommodation effect such a refractive process, and, as Helmholtz found, by means of his ophthalmometer, in the following manner:—

1st. The pupil diminishes in size.
2nd. The pupillary edge of the iris moves forward.
3rd. The peripheral portion of the iris moves backwards.
4th. The anterior surface of the crystalline lens becomes more convex (and so acquiring a higher power of refraction, and consequently a shorter focal length), and its vertex moves forward.
5th. The posterior surface of the crystalline lens also becomes slightly more arched, but does not perceptibly change its position; the lens, therefore, becomes thicker in the centre.

And from calculation he found that these changes in the crystalline lens are quite sufficient to account for all accommodative purposes.

The diagram in the next page, after Helmholtz (Fig. 3), shows the changes which the eye undergoes during accommodation. The anterior portion is divided into two equal parts: the one half, I, shows the position of the parts where the eye is adjusted for distance; the other, F, when it is accommodated for

Fig. 2.

near objects. When the eye is in a state of rest, the iris forms a curve at *a*; when accommodated for near objects, the fibres of the iris become contracted, the periphery of the iris straightened at *b*, and the anterior chamber lengthened, thus making up for its loss in depth, through the advance of the anterior surface of the crystalline lens. The anatomical mechanism by which this accommodation is effected is yet an open question, but as it is one of physiological rather than optical importance, it need not be herein discussed.

* The rays emanating from a far distant object, such as the sun, moon, or a star, are regarded optically as parallel, but practically, even when an object is only placed at eighteen or twenty feet distance the rays from it, though really divergent, are yet so slightly so, that to all intents and purposes they impinge parallel upon the eye. We therefore consider rays coming from an object further than eighteen feet as parallel, and emanating from an object at an *infinite distance*. On the other hand, rays coming from a nearer object fall upon the eye in a divergent direction (the divergence being in proportion to its proximity), and are then considered as coming from a *finite distance*.

It is assumed that when the normal eye is in a state of absolute rest, parallel rays (emanating from objects at an infinite distance) are brought to a focus on the retina, and that a positive change in the accommodative apparatus of the eye is only required for objects at a finite distance; but it is thought by some ophthalmists that the eye when in a state of rest is adjusted neither for its far nor for its near point, but for a distance between the two, and that adjustment for either nearer or more distant objects necessitates an effort of accommodation. Such authorities call the adjustment for near objects *positive*, and that for distant objects *negative* accommodation.

It may be here noted that every eye has its "*blind spot*," which is situated at the point where the optic nerve enters the eye, and from which it ramifies to form the network of the retina; and if the image of an object is made to fall upon that spot it will be invisible, as the *punctum cæcum*, as it is called, is insensible to the action of light. This may be proved in the following manner:—Lay two black wafers on a sheet of white paper three inches apart, and at a distance of ten or eleven inches, bring the right eye exactly over the left-hand wafer, so that the line joining the two eyes shall be parallel to the line joining the two wafers. On closing the left eye, and looking steadily with the right at the left-hand wafer, the right-hand one ceases to be visible, as in this position its image falls upon the "blind spot."

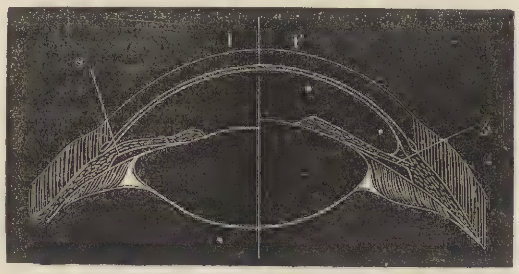


Fig. 3.

As the normal eye performs its delicate functions to perfection, it is evident that the interference of the optician can never be required, excepting to give relief when the organs of vision are weak or suffering from inflammation, in which case an ordinary spectacle-frame fitted with a flat piece of tinted glass may be furnished to the patient; or when it is necessary to carry this protective appliance to greater perfection, a frame may be supplied with what are called "*glazed wings*," shown in Fig. 4; while the most perfect guard is to be found in a frame fitted with tinted glasses and a shield of fine black gauze that fits close around the socket of the eye, shown in Fig. 5.

The glass employed in the construction of these "Protectors" may be obtained of various colours and tints, green and blue being chiefly employed; but the tint that admits the least amount of glare, and yet allows of the greatest amount of distinct vision, is a neutral blue, the value of which has been recognised by most ophthalmic surgeons and oculists.

Tinted protectors of this nature may also be given with advantage to travellers to guard them against the injurious reflections from Alpine snows or the radiation from hot desert sands. Fitted with very dark glasses, they may also be recommended to those who have received injury to the eyes, in order to disguise the disfigurement.

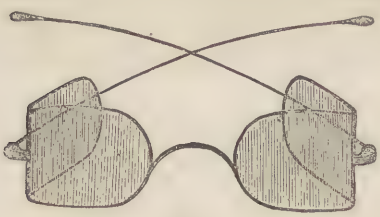


Fig. 4.

In violent or in chronic inflammation of the eyes the optician is often applied to for a shade that will give more ventilation than the home-made article will allow of; the best arrangement is one wherein the shade is supported on the head by a metal frame in such a manner as to throw the upper edge of the shade slightly from the forehead so as to allow a current of air to pass over the eyes, while by a pivot attached to the frame the shade can be thrown back when necessary.

The optician is also often required to furnish an "eye douche," by which the organ can, in certain cases of irritation or weakness, be bathed. These usually consist of an elastic syringe, by which water or medicated liquid can be projected on the eye with any amount of force, connected by an india-rubber tube with a glass cup that surrounds the eye while being used, and to this cup another tube is attached to carry off the liquid into a basin. Where the eye is to be subjected to the influence of stimulating vapours, a stoppered bottle, constructed with an oval-shaped cup to fit the socket of the eye is employed.

The optician is frequently requested to supply eye-glasses or spectacles to persons who, they soon discover, are in no way affected in their organs of vision—in fact, are blessed with a normal eye. As a rule, such individuals desire what may be called a "dandy glass" to stick in their eye-sockets, with which to assume a supposed fashionable appearance, and further, that this shall be supplied at the lowest possible price. The article best suited to meet the want in such cases is a disc of *plane* white glass with a hole drilled in it for the insertion of a thin silk cord, by which it can be attached to the person. It need scarcely be stated that such a glass must be perfectly devoid of all optical properties. In other and similar cases spectacles are desired to give the wearer a thoughtful or learned appearance; in such instances two plain glasses (not lenses) are required instead of one, which might be called "snob glasses." In rare cases it may be found that aged persons of good constitution are desirous of purchasing a pair of spectacles, not from any absolute shortcoming of sight, but from a notion that as friends of similar or greater age required the optician's aid, *they* also *ought* to wear them. In such instances the applicants may be tested with convex and concave lenses before the real state of the case is discovered, as they see better with the naked eye than with spectacles of the lowest power. The proper course is to state that spectacles would do more harm than good, a piece of advice that would be quite thrown away in the former cases.

Range of Accommodation.—When the eye has assumed its highest state of refraction, it is accommodated for its *nearest point* of distinct vision; when, on the other hand, its state of refraction is relaxed to the utmost, it is adjusted for its *furthest point*.

The distance between the furthest and nearest point of distinct vision is called "*the range of accommodation.*"

As increase in the convexity of the crystalline lens is limited, its power of accommodation for near objects is also limited, and the "*near point*" cannot be brought nearer than a certain distance to the eye. In normal eyes the nearest point of distinct vision lies at about $3\frac{1}{2}$ inches to 4 inches from the eye; this varies, however, according to age, for the near point recedes further and further from the eye with increasing years.

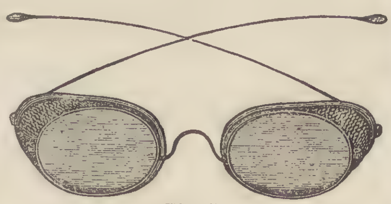


Fig. 5.

Where professional occupation, such as engraving, needlework, etc., necessitates continued work at near objects, the near point for distinct vision lies at about five inches from the eye. Few eyes, it should be observed, can bear to work for any length of time with the object nearer than this.

The furthest point of distinct vision in the normal eye is at an infinite distance. The amount of this "range of accommodation" varies according to the strength of the ciliary muscles, the elasticity of the crystalline lens, and other minor causes. It is most important that the optician should carefully determine the "range of accommodation" for each patient according to the method hereafter given, as it affords a means of safely discovering whether the eye is normal, presbyopic, hypermetropic, or myopic, and the kind of lens exactly suited to each particular case, together with the most suitable focus for such lens.

CIVIL ENGINEERING.—II.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DRAINING.

WORKS of drainage are of two kinds:—1st. Those which relate to the reclamation of land from the encroachments or accumulation of tidal and other large bodies of water. 2nd. Those which relate to the removal of sewage from towns. As respects agricultural drainage—by which we mean the improvement of the soil by the removal of mere surface moisture—as it does not come within the province of Civil Engineering, we shall make no further allusion to it.

The value of the land overflowed by tidal waters, or by waters subject to rise and fall through floods and drought, is almost always very considerable, owing to the marine or alluvial deposits which remain upon the soil. Some of the component parts of sea-water are highly fertilising; indeed, in many districts, especially in Scotland and Ireland, sea-weed forms the only manure employed by the farmer. Hence it has been found worth while to expend vast sums of money in order to shut out the water, and to drain the soil over which it had spread.

It is a matter of no ordinary difficulty to contend against the variations and alternations of pressure produced by water whose level is perpetually and rapidly changing. This difficulty reaches its maximum in the case of tidal waters, especially of such tides as are experienced upon our own shores, where, in less than the space of twelve hours, there is a rise and fall of from fifteen to twenty-four feet. The immense rush of water in or out of any passage communicating with the tides, renders the greatest caution necessary, lest the barriers intended to withstand the pressure should be carried away before being sufficiently consolidated. And yet in the face of these engineering difficulties, a vast portion of the low land in Holland has been reclaimed from the sea; and in this country upwards of half a million of acres of land in Norfolk overflowed at one period by the joint action of the sea, and the rivers Witham, Welland, Ouse, and others, have been converted into some of the richest agricultural districts in England, from being, at one time, pestilent marshes. How these particular results were brought about it is not our purpose to explain; our object is rather to state briefly the usual course adopted in operations of this kind. It is not, however, possible to lay down any rule of action, since each operation will require some special arrangements applicable to the particular locality; these matters must be left to the discretion of the engineer.

Before commencing a main barrier of any kind, whether of piles, earth, or caissons, it is desirable to ascertain, by a careful survey of the flooded districts and an examination of the levels, how far a judicious arrangement of canals and ditches may not avail to carry away a large amount of water by the mere effect of gravity, and also whether or not an ordinary dyke or bank of earth, stretched across a back-lying portion of drowned land, may not successfully diminish its area, and thus render less difficult the final operation of closing the entrance to the tide, when this has been reduced to a minimum by subsequent operations. These simple operations will frequently save an immense amount of labour, for it is obvious that the larger the area of the submerged land, the greater will be the rush or *scour* of the tide as it flows over it.

Whenever banks are erected across a flooded district, they should be constructed with *sluices* or *flood-gates*, which can be opened or closed when required, so that advantage may be taken of a lower state of the water-level upon the tidal or outlet side, to discharge the excess upon the land side. It is also of advantage to construct self-acting sluices or outfalls, which are simply strong doors or flaps of timber, iron-hinged at their upper edge, and opening only *outwards*, so that whenever the level is higher upon the land side, the greater pressure of water automatically opens these doors, and a discharge continues until uniformity of level is gained, when the doors close by their own weight, and falling against a *sill*, effectually prevent the return of the discharged water. These sluices, to be of most service, must be constructed low down in the dyke, and being usually out of sight, should be constructed with great care, as any derangement in them would cause disastrous results.

It frequently occurs that an accumulation of fresh water arises from the simple overflow of a river during heavy and continuous rains, or a sudden thaw. Such floods are of frequent occurrence in the south of France, and cause serious loss of property and life. The remedy in this case is simple and obvious, although it may involve a considerable outlay. The banks must either be raised and strengthened, or the channel must be deepened and widened, or additional channels must be cut; the end being in either case gained when the sectional area of the water-course is equal in every point to the volume of water which has to pass it in a unit of time.

In the case of tidal waters, the operations are very difficult; the rush of the *in*-flowing water at every flood-tide, and of the *out*-flowing at every ebb, and the consequent *scour* produced by this rush, has to be met, and the smaller the opening or gap, as compared with the tract of land covered at each tide, the greater will this rush be; and it is only a barrier far more substantial than it is possible to place across any large opening, in the short period allowed between tide and tide, that will suffice to withstand the force of the current in the tide-way. Hence it is necessary to reduce the width of the tide-way to a minimum before attempting to close it. The most substantial barrier, and the cheapest whenever it can be employed, is *earth;* but this is useless to stop an opening through which a violent rush of water occurs, as the soil will be carried away as fast as it is deposited. Earth can, however, be safely and advantageously employed as a base for further operations; using it in all cases where the flow of water is inconsiderable, and thus gradually narrowing the tide-way. When this embankment (strengthened according to discretion with piles) has been carried as far as it can be with safety, there then remains the tide-way to close up.

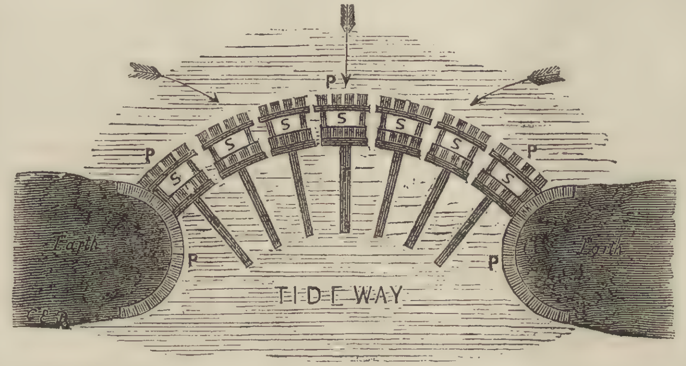


Fig. 1.—BARRIER AT THE MOUTH OF A TIDAL BASIN.

There are two methods of doing this. If the depth of water in the channel will admit of it, a double semi-circular or curved row of piles (P P P, Fig. 1) may be driven at short intervals apart across the opening, leaving a space (S S S) of twelve or eighteen inches between the two rows, which are to be strengthened by cross-ties, braces, and struts (T T T).

The curve must be outwards, and the driving of the piles should commence from each side and finish in the centre. At the ends of the curve, the piles abut upon other piles driven closely together, and forming a protection for the extremities of the earthen dyke, which would otherwise be subject to injury by the *scour* of the water. Barges of stiff, broken clay and stones should be floated near the outside of the piles, and plenty of labour ought to be at hand in order to take prompt advantage of the moment of low water. The clay and stones must then be rapidly shot into the space between the rows of piles; and if the organisation of labour be good, it will be quite possible to keep pace with the rise of the tide in the deposit of the soil, and even to impart a certain degree of solidity to it by ramming. Such a barrier has the elements of great strength in it; and although it may not be altogether impervious to water, it will suffice to prevent any considerable flow, and will entirely stop

a rush or scour, thus enabling the permanent embankment to be completed, after which the piles can be removed.

The plan we have indicated will not, however, avail in all cases. The depth of water in the tide-way may be too great to admit of piles being sunk sufficiently deep into the soil to gain a firm standing, or the area of the land overflowed at every tide may be so extensive, that it will be found impossible to narrow the tide-way by a continuous earthen embankment sufficiently to admit of a barrier of piles withstanding the pressure.

In such cases the following course may be adopted:—Let the embankment contain, at frequent intervals, large flood-gates, constructed during the progress of the work, which can be opened and shut at pleasure. When the gates are open, the flow of the tide is spread over an opening equal to the joint area of the space between the extremities of the embankment and that of the flood-gates, and will, consequently, be less in the unfinished opening when the gates are open than when they are closed. The scour of the tide being thus reduced, the embankment can be continued until the space of the tide-way is reduced to a point sufficiently narrow to admit of the same course being adopted as shown in Fig. 1. The embankment can then be completed, and the gates being closed at low tide, the level of water over the enclosed space will be proportionately reduced.

Under almost all conditions of the drainage of flooded lands, a surplus of water will remain even after all communication with the tide has been cut off, and this surplus must be removed or kept under by pumping. Wind or steam power may be necessary, indeed *will be*, if the submerged district is extensive.

The better kind of pump for the purpose is the "V," the "chain," or the "centrifugal," as the grit which enters the pump with the water is sure to act detrimentally upon the ordinary barrel and bucket pump, destroying the leather and choking the valves.

Constant attention must be paid to the sluices, "clows," and gates, owing to the great pressure they are frequently subjected to, and in consequence of the serious results which would ensue from their failure. An idea of the pressure exerted by water, when any considerable difference of level exists, is formed by the fact that, at the mean height of the tide—sixteen feet above low-water mark—the pressure exerted upon each square foot of surface at the bottom is 1,152 lb., and half this, or 576 lb., represents the actual mean pressure exerted by a high tide upon every vertical square foot of an embankment.

The magnificent stone embankment recently constructed on portions of both the north and south sides of the Thames, and which has for its object, amongst others, the narrowing of the channel in order to cause a greater scour of water to remove the accumulated mud, was carried out behind a protecting wall of closely-fitting piles, in one portion, and of cast-iron shields, dovetailed together with piles, in another. The percolation of water from the river, which was considerable, was kept under by steam-pumps. The granite wall was completed behind the wall of piles, and soil afterwards "tipped" into the space on the land side. The foul black mud has thus been buried, and the space it formerly occupied devoted to a splendid carriage way, a subterranean railway, and one of the principal culverts connected with the main drainage system of the Metropolis.

Sanitary Drainage.—But one opinion can exist as to the necessity for removing sewage from the vicinity of an inhabited district, although a variety of opinions are held as to the best mode of disposing of it. It is foreign to our purpose to adduce the various arguments which have been raised for or against any particular system of drainage, and we shall merely state what are the various plans adopted.

I. We consider the most desirable plan, when practicable, is entirely to remove the offensive matter as far as possible from the inhabited locality. This plan has been carried out at great expense in the drainage of London.

In all cases of sanitary drainage it is necessary to provide for the passage of rain-water as well as of mere sewage. An estimate of the rainfall in any particular locality, formed by taking an average of a succession of years, is hardly sufficient; it is better to select the *maximum* rainfall in one day of a series of years, and provide an excessive area in the culverts for such a maximum, so that no danger from the flushing of the sewers shall arise, even during a period of flood. This question was very carefully considered in dealing with the main drainage of the Metropolis.

To reduce the amount of pumping to a minimum, it is desirable so to arrange the levels of the sewers as that as much as possible of the sewage shall pass away by gravitation. If the area to be drained were either a uniform level standing a definite height above the river or sea into which it is intended to discharge the sewage, or stood upon a regular slope down to the point of discharge, no pumping would be needed; but when the ground is uneven, and some of it lies lower even than the level of the outfall, it will become necessary to pump the drainage from the lower levels into the higher, from which alone the discharge can be effected. How best to arrange these levels is a question of the highest moment in planning out the positions of the sewers.

The uneven nature of the ground occupied by the Metropolis necessitated three different lines of sewers, each occupying a different level. These, known as the High, Middle, and Low level sewers, are thus arranged:—Upon the north side of the Thames the three lines converge and unite at Abbey Mills, near Bow, where the contents of the Low Level are pumped into the Upper Level sewer, and the aggregate stream carried across the marshes to Barking Creek, through the northern outfall, and there discharged into the river at the period of high water. The theory involved in this arrangement is, that as the flow of water towards the sea consists, during the period of ebb tide, of the land water *plus* the tidal water, the period of *ebb* tide is longer than the period of *flow;* hence any object free to move up and down the channel of the river by the action of the tide, will be carried nearer and nearer the sea at each successive tide. Such occurs with the sewage. It is retained in an immense reservoir near the outfall, until the period of high water, and then discharged during a certain time, the time at which the discharge is stopped being regulated by the state of the tide: the reservoir being arranged to contain an accumulation of eleven hours' sewage. The great object is that the sewage, after its discharge into the river, shall never be brought back by the action of the tide to the Metropolis, and this is entirely effected by placing the outfalls from twelve to thirteen and a-half miles by river below London Bridge.

The section of the sewers is for the most part circular, as combining the greatest strength and capacity with the least cost of labour and material.

The smaller and subsidiary branches are egg-shaped, in order to obtain the greatest *scour* with a minimum amount of flow. This shape was adopted by the Romans in the Clôaca Maxima which drains the whole of Rome as well as the Campagna. This culvert is fourteen feet wide and thirty-two feet high, and its area is nearly sufficient to drain the whole of the metropolitan district. Its section manifests a considerable knowledge of the power of deep water for scouring the bottom of a sewer, and thus removing the deposits.

The metropolitan culverts are for the most part constructed of brickwork set in cement. Their area varies from four feet diameter to nine feet six inches by twelve feet. The thickness of the brickwork also varies from nine to twenty-seven inches.

The necessity for maintaining a nearly uniform gradient in the lines of sewers, and more particularly the necessity of making the gradient *always in one direction*, compelled them to be carried over or under every obstacle. As an instance of this, we may state that the Middle Level sewer, on the north tide of the river, is carried over the Metropolitan Railway near Farringdon Street by a wrought-iron aqueduct of 150 feet span; its weight being 240 tons.

A similar system of drainage is carried out on the south side of the river, the convergence of the three levels being at Deptford Creek, where also is situated the pumping-engine for raising the sewage from the Low Level to the High Level sewer, a height of eighteen feet. The southern outfall passes thence to Crossness, about one and a-half miles further down the river than Barking Creek.

We append a summary of the principal points of engineering interest in this great work. The total cost of the main drainage works, when completed, will be about £4,100,000, a sum raised

by loan, and paid off by a 3d. rate levied on the Metropolis, producing £180,262 per annum. It will require forty years to pay off both principal and interest.

There are 1,300 miles of sewers in London, and eighty-two miles of main sewers; 318,000,000 bricks, and 880,000 cubic yards of concrete have been consumed; and 3,500,000 cubic yards of earth have been removed in the progress of the work. The total pumping power employed is 2,380 horse-power nominal, and the annual consumption of coal is about 20,000 tons.

The sewage on the north side of the Thames is over 10,000,000 cubic feet per day, and over 5,000,000 on the south side. In addition to this, provision is made for 28,500,000 cubic feet of rainfall per day on the north side, and 17,250,000 on the south side; the total being equivalent to a lake fifteen times as large as the Serpentine. The reservoir at Barking is 16¾ feet deep, and covers an area of about 9½ acres; that at Crossness, with an equal depth, has an area of 6½ acres.

The importance of this great engineering work cannot be overrated. It has totally changed the sanitary condition of large areas of the Metropolis; and although not fully completed, has effected an improvement in a sanitary point of view of which the cost of the undertaking forms no criterion.

We have entered somewhat largely into the details of this work, as it forms the best example of that system of drainage which aims at conveying away bodily the refuse matter.

II. Many persons are of opinion that to convey away and discharge into a river so enormous a quantity of sewage is a twofold evil: it poisons the water, and wastes a valuable fertilising agent. Those who hold this opinion differ, however, as to the manner in which they would treat the sewage. In some instances, as at Croydon, the sewage is applied to the entire level surface, irrigating the plants or grass at once. In other cases, as at Romford, the ground is intersected by numerous shallow trenches, into which the sewage is pumped, the plants being embedded in the soil adjoining the trenches. The sewage thus passes to the roots through the medium of the soil. The whole district thus irrigated is itself drained, and the effluent water pumped back into the trenches. There can be no question as to the value of sewage for agricultural purposes. The sewage of London is estimated as worth £1,500,000 annually. Its value, as shown at South Norwood, is such, that over fifty tons of Italian rye-grass have been grown the acre in each year, worth from £30 to £40. This grass has been produced from six successive crops in the twelve months, and the aggregate length of the blades is equal to fifteen feet. At the same time it is asserted that the sewage, after being thus utilised, is actually as pure as the water supplied by some of the Metropolitan water companies, in the proportion of 23 to 21 grains of organic matter per gallon.

III. There is yet another system adopted with respect to sewage. Leamington and Hastings are the chief localities where this system has been carried out. It is known as the "A B C" process. Under this system the sewage is first deodorised and precipitated, the effluent water being allowed to pass away into the sea or river, the solid residuum being utilised as manure.

The "A B C" is a patented process, and obtains its name from the initial letters of the three principal ingredients used in the process of defœcation, *alum*, *blood*, and *clay*. Other substances are employed: for instance, the sulphate or carbonate of magnesia, manganate of potash, chloride of sodium, animal and vegetable charcoal. A mixture in certain proportions of these substances is added to the sewage so long as precipitation takes place; the average quantity required being 4 pounds of mixture to 1,000 gallons of sewage. The partially dried precipitate has a small quantity of sulphuric acid added to it to fix the ammonia, and it is then regarded by the patentees as a valuable manure.

MINERAL COMMERCIAL PRODUCTS.—VI.

SILICIOUS SUBSTANCES (*continued*).

SERPENTINE, so called from the supposed resemblance of the mineral to the skin of a serpent, is a silicate of magnesia with adventitious admixtures of lime, alumina, iron, chromium, etc., and occurs as a rock or in association with other minerals constituting rock masses. The west of Mayo and Galway are remarkable for their serpentine rocks, which afford the beautiful variegated green and white varieties worked into pilasters, columns, etc. Serpentines and serpentine limestones of great beauty and excellent quality are also quarried in different parts of the county of Cornwall, the Shetland Isles, Canada, the United States, Italy, etc.

Basaltic and kindred rocks—greenstone, whinstone, and trap—are intrusive rocks, for the most part felspathic. Some of these are well adapted for building, but their great use is for paving and macadamising roads, for which purposes they are unrivalled. The columnar structure of basalt is in some places taken advantage of for the construction of stone posts and window-sills. These rocks are abundant in many parts of Scotland, and occur also in Ireland, various districts of Germany, and Nova Scotia.

Lava, a volcanic production, is often similar to trap, and equally useful. It occurs in recent and extinct volcanic districts. *Obsidian*, a volcanic glass, usually black, and somewhat resembling the slag of a glass furnace, is found in Mexico, Central America, Peru, Iceland, etc. *Pumice-stone*, a well-known porous and extremely light stone, used for polishing, etc., and *Pozzuolano* and *trass*, silicious earths much used to mix with limes for hydraulic cements, are also volcanic productions, of which the chief mineral ingredients are augite and felspar. Pumice-stone is quarried in the small islands that lie off the coast of Sicily. Pozzuolano and trass are obtained from Italy, and from many districts of France, Germany, and Scotland.

CLAYS AND ALLIED SUBSTANCES.

Clays, which are silicates of alumina more or less pure, occur in all formations from the firmest slates of the older rocks, and the loose shales of the Carboniferous and the Secondary, to the plastic clays of the Tertiary and the alluvial deposits. They enter largely into the materials and processes of building, as slates, tiles (both for roofing, paving, and ornamental purposes), and bricks; into the manufacture of pottery and earthenware of all sorts, terra-cotta, and many other useful applications.

Common clay, so abundantly diffused over the earth's surface, and chiefly distinguished into three varieties—yellow, brown, and blue—furnishes material for the builder and the maker of the common pottery wares. China and porcelain are made from the fine clays called *kaolin* and *petuntse*, which are almost pure, and are due to the decomposition of the felspars of granitic rocks, the felspar containing soda being especially liable to disintegration. These clays are found in Cornwall, Devon, France, Belgium, and Germany, but can also be artificially prepared. *Pipe-clay* is a white, pure variety, with an excess of silica. It is obtained from Poole and Purbeck. *Fire* or refractory clays, used in the manufacture of fire-bricks, retorts, and crucibles, contain a preponderance of silica over alumina, and occur chiefly in the Carboniferous strata. In England the Stourbridge clay is famous for these purposes. Belgium, and Siegburg in Germany, also furnish fine clays. Others, however, sufficiently pure, can be made available to some extent by the addition of silicious sand. *Fuller's earth* is a very useful clayey substance, having in its composition a large proportion of silica and a quantity of water. It is employed in the preparation of wool, and is abundantly met with in Surrey, Buckingham, Hampshire, Gloucestershire, and Bedford. The *ochres*, chiefly red and yellow, are mixtures of clay and oxides of iron. They are used in the manufacture of colours; the most suitable for this purpose being obtained near Oxford, in Fife, in Antrim, Italy, and other places.

Slates, from their natural cleavage and their great durability, are of extreme utility for a variety of purposes, chiefly roofing, the construction of cisterns, and the manufacture of school slates and pencils. The best are those which are hardest and finest in grain. Besides the common colour, there are green, purple, and grey slates. The laminæ are of different thicknesses, and are used accordingly. Slates are quarried chiefly from rocks of ancient date (Silurian and Cambrian), and are abundantly supplied from Penrhyn, Llanberis, Festiniog, and other parts of Wales, as well as from Cornwall, Devonshire, Westmoreland, Scotland, Ireland, France, Belgium, Germany, and Asia.

Hone stones, of which there are many varieties, are slaty stones which are used in straight pieces for sharpening tools after they have been ground on grindstones. The most important varieties are the following:—Norway ragstone, the coarsest variety, imported in large quantities from Norway; Charnwood Forest stone, one of the best substitutes for the Turkey oil-stone, much in request by joiners and others, and obtained from Charnwood Forest, Leicestershire; Turkey oil-stone, of which there are two varieties, white and black, the latter being the harder, surpassing every other oil-stone, used by the engraver, and obtained from the interior of Asia Minor; Ayr stone; snake stone; Scotch stone, used especially for polishing copperplate; Welsh oil-stone, second only to the Charnwood Forest stone, and obtained at Llyn Idwall, near Snowdon, whence is also obtained the "cutler's green stone;" and the German razor hone, derived from a yellow band in the blue slates of the neighbourhood of Ratisbon.

EARTHS OF SODIUM, POTASSIUM, BORON, SULPHUR, ETC.

The elements, of the combination of which we are about to speak, do not, for the most part, occur naturally in their simple state, but their compounds, especially those of sodium, potassium, and sulphur (which is also native), are numerous, abundant, and valuable.

Common salt (chloride of sodium) is an extremely abundant and quite an indispensable commodity. It exists in sea-water and salt lakes, in the proportion of from 3 to 4 per cent., or even more in some of the lakes, and can be extracted by evaporation. It occurs in a much larger proportion in many brine-springs connected with geological deposits of salt, but these deposits themselves form now by far the best sources of supply. Rock-salt is obtained in England principally from the mines of Cheshire, and also near Belfast; culinary salt is manufactured in large quantities in Cheshire and Worcestershire from brine springs; in both cases, the salt is derived from the Keuper marls of the New Red Sandstone system, in which it occurs in basin-shaped deposits, and is arranged in wedge-shaped masses. Salt-beds occur in rocks of various ages; those of Nova Scotia in the Carboniferous system; the rock-salt of Ireland, England, and Prussian Saxony in the Keuper formation; that of the Carpathian Alps in the Upper Oolite; that of Poland and the Pyrenees in the Cretaceous series; and that of Pisa and Cuba in the Miocene rocks. Beds of salt occur also in China, and many districts of North America. Some of the salt mines of Europe furnish perhaps the most stupendous examples of mining industry. Salt for domestic purposes is refined from the more or less impure native product, and from it also common soda (carbonate of soda)—formerly made, like barilla, from the ashes of sea-weeds, etc.—is manufactured on an immense scale. Chlorine for bleaching and disinfecting purposes is also very largely supplied from the same source. Many parts of the earth being deficient in the supply of salt, it is an important article of commerce, and 600,000 tons are annually exported from this country, the yearly produce of which exceeds 1,500,000 tons.

The *Alums*, already alluded to under the head of *Aluminum*, are important compounds of sulphate of alumina with sulphate of potash, or soda, or ammonia, potash being the most common. Alum occurs native to a small extent, but from its great value in the arts, especially in dyeing and calico printing, it is manufactured on a large scale. One process is to treat clay with sulphuric acid, by which a sulphate of alumina is formed, to which potash, soda, or ammonia is added, and the resulting crystallised salt is accordingly either a potash, soda, or ammonia alum. Alum is also made from *alum slate* or *shale;* this substance contains alumina, protoxide of iron, a trace of potash, and iron pyrites dispersed through it. This pyritous shale, on exposure to the atmosphere, undergoes decomposition, which is accelerated by the manufacturer, who, availing himself of the carbonaceous character of the shale, applies fire to the alum shale heap. The iron pyrites is changed into sulphate of iron, which forms, with the alumina, a double sulphate of iron and alumina; this is subsequently purified by evaporation, and by the addition of potash the salt is rendered crystallisable. Glasgow, Whitby, and Newcastle are the chief localities of alum manufacture in this country. The best alums are those prepared in Asia Minor and Italy. China produces a considerable quantity, and Tuscany an average of 7,000 tons per annum.

TECHNICAL DRAWING.—VIII.

WOODEN BRIDGES (*continued.*)

THE structural portions of the bridge having been completed, the hand-rail may now be commenced.

Having drawn the top rail and the standards which divide the length into ten equal rectangles, draw diagonals in each; then the lines forming the cross-struts are to be drawn parallel to these. The longitudinal and transverse sections will not, it is presumed, require further instruction, and we can therefore turn our attention to the next series of examples of hand-rails.

The most simple of these is Fig. 43. In beginning this it is best to draw the section (Fig. 44) first, as from it the elevation of the cornice and of the horizontal bars must be projected.

Having, then, drawn Fig. 44, draw horizontals from the different points in the section of the cornice, *a*, and from the top and bottom of the section of the top rail, *b*.

Next draw the standards, *c c;* then from the angles of the square middle rail, *d*, project the elevation, *d*, which will complete the figure.

Fig. 45 is an enlarged elevation of the hand-rail already shown in Fig. 40. Here the section (Fig. 46) is to be drawn first, excepting the part *d d*, which is determined according to the angle at which the struts cross each other. Having, then, projected the elevation of the top rail and cornice from the section, draw the standards, *c c*, and diagonals in the rectangle.

Now let us suppose (as would in practice, of course, be the case) that the struts are to be of a definite width. To set this off accurately, draw a line through each diagonal, at any part, but at *right angles* to it. On these, on each side of the diagonals, set off from the intersection half of the width of the struts; then lines drawn through these points parallel to the diagonals will give the sides of the cross-pieces required.

It will be seen that the lines thus drawn will at their intersection form a lozenge or diamond-shape; from the lower and upper angle of this figure draw horizontals, which will give the section, *d d*, in Fig. 46, and in this the central vertical line will show that the struts in crossing are "halved" into each other, so they are "flush" with the uprights and with the upper rail. The splaying of the edges can, of course, be done without any further guidance.

Fig. 47 is a hand-rail of a similar character to the last, but the space between the standards is to be filled with two pairs of struts at right angles to each other. Now the space is doubly as long as it is wide; therefore divide it into two equal squares, in which draw diagonals. On these, set off from their intersection half of the width of the struts, and draw the lines which form the edges of them; the section (Fig. 48) can then, as in the last figure, be completed from the elevation.

Fig. 50 is a mere trellis-rail, and will be found very easy to draw; but care is required so that all the interstices may be *equal squares.*

Having drawn the section (Fig. 49), and projected the cornice and upper rail in the elevation (Fig. 50), draw centre-lines for each of the cross-pieces, which will be readily accomplished by means of your set-square of 45°. On each side of the intersection set off half the width of the pieces, and draw the lines; it will thus be seen that this is a repetition of the last figure, but with a multiplication of parts.

We still continue using wooden bridges as examples for drawing, not because they are as much used in this country as they were in times gone by, but because the principles of their construction convey so much instruction, which will be of service in the subsequent section on "Roofs." And further, in these days of railways and emigration, some knowledge of the construction of bridges of a material which is so generally available cannot fail to be of service.

Fig. 51 is partly an elevation and partly a longitudinal section of a covered wooden truss-bridge, such as is frequently used for passengers to pass from one platform of a railway to the other.

Here it is necessary briefly to remind the student of the action of a *king-post*, viz., that when the lower ends of the principal rafters (two strong timbers, *which together* are longer than the space to be bridged over) are mortised or otherwise fixed by their lower ends to the tie-beam, the upper ends abutting against the head of the king-post, this acts as the key-stone of an arch, and being lengthened, the tie-beam is bolted or strapped up to it. This principle, illustrated by the necessary

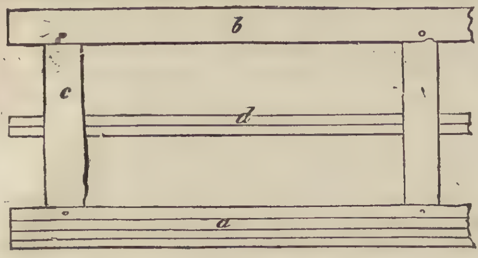


Fig. 43.

Fig. 44.

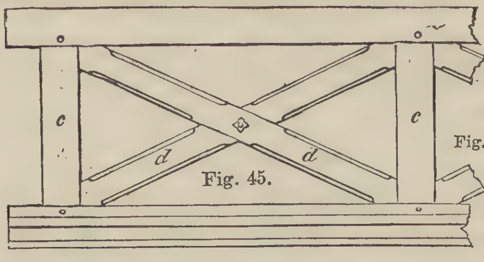


Fig. 45.

Fig. 46.

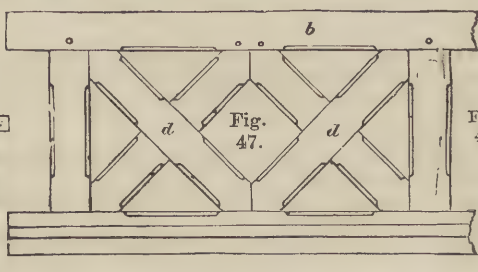


Fig. 47.

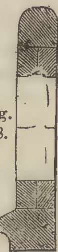


Fig. 48.

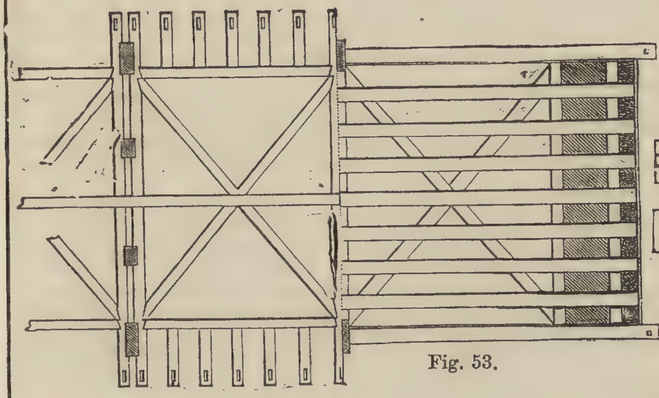


Fig. 53.

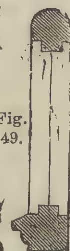


Fig. 49.

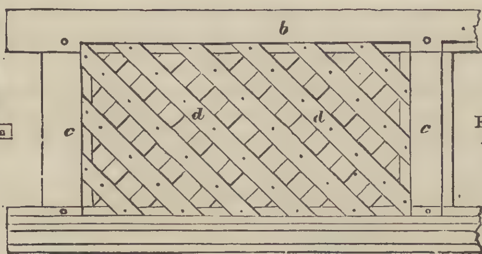


Fig. 50.

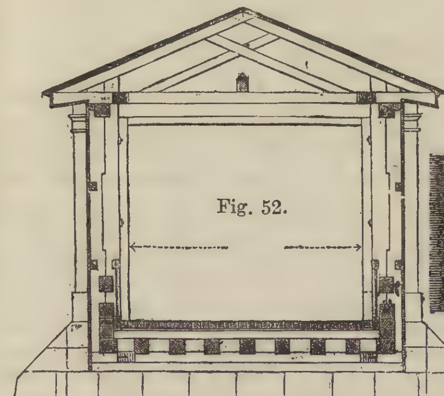


Fig. 52.

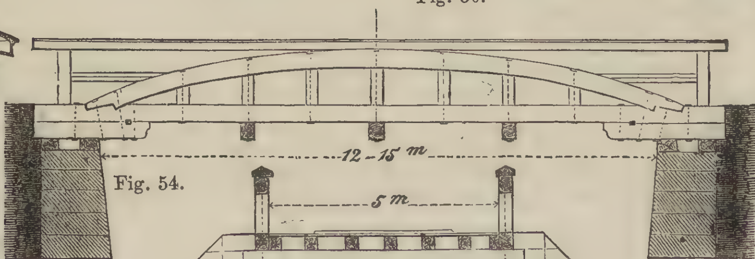


Fig. 54.

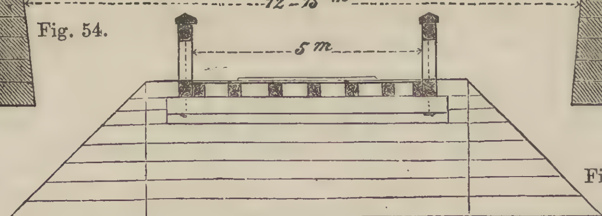


Fig. 55.

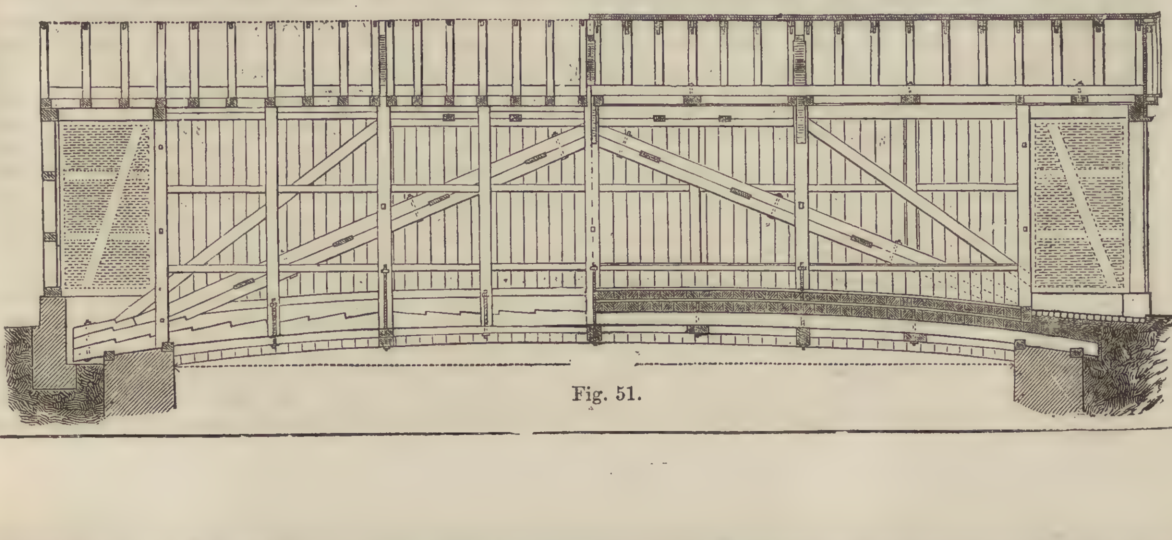


Fig. 51.

diagrams, is treated of in "Building Construction," and will be further worked out in connection with roofs.

In the present example the tie-beam is built up of two equal timbers, which are scarfed or toothed into each other, and the king-post, being also double, clasps the tie-beam at the bottom. Underneath the tie-beam a transverse bearer passes from one king-post to the other, and these being screwed up by means of screw-bolts, the tie-beam is drawn up into a curve. The principals, too, are made up of two equal lengths.

In addition to this there are queen-posts, which are supported at the top by means of a collar-beam and struts; and to these, bearers passing transversely under the tie-beams are bolted, like those under the king-posts. There are also intermediate suspending posts, from which bearers are not suspended, but to which bolts pass through the tie-beams.

The half of Fig. 51, which is given in section, will show the manner in which the planks forming the floor of the bridge are laid, and the longitudinal girders resting on the transverse bearers are shown in the section (Fig. 52), in which the simple roof timbers are also shown.

Fig. 53 is a horizontal section, showing the diagonal straining-pieces between the bearers.

A few instructions on the method of drawing this subject (Fig. 51) will now be given.

First draw the piers, and a straight line uniting their springing points.

Bisect this line, and in the perpendicular set off from the intersection the height of the curve from the horizontal line. There will then be three fixed points—viz., the two springing points, and that in the perpendicular.

Now it will be remembered that if these points be joined, and the lines uniting them be bisected, the intersection of the bisecting lines will be the centre of the circle of which the arc is a part. (See Fig. 10, "Practical Geometry.")

Having, then, thus found the centre, describe the arc forming the under side of the tie-beam. The arcs under this are to be drawn with the same radius, moving the centres a little lower down on the perpendicular.

The tie-beam is rather broader in the middle than at the ends, and therefore the upper arc must be struck with a rather shorter radius, the centre being slightly higher than that from which the under side was drawn; from a point half-way between these two centres an arc must be struck, exactly between the upper and lower edges of the tie-beam, and on this the toothing of the scarf is to be drawn.

Now proceed to draw the king-post, measuring half its width on each side of the central perpendicular, then the principal rafters, the collar-beam, and the longitudinal joist above it; then follow the queen-posts, the suspension-pieces, and the ends of the bearers.

The foundation for the fronts, and the fronts themselves, are now to be drawn; then the ridge and the rafters.

After this the boarding of the sides of the bridge is to be filled in, and any other detail which may not have required separate mention.

Figs. 52 and 53 are too simple in their lines for the student to need any instructions as to the mode of drawing them; he is simply advised to draw the different parts in the order in which they have been explained in the elevation.

Fig. 54 is a side elevation of a small bridge constructed on the "bow suspension truss" principle.

Here the bow, consisting of a single beam, is mortised into the ends of the tie-beam, which are in their turn strengthened by saddle-pieces, bolts passing through these saddle-pieces, the tie-beam, and the bow.

At regular intervals perpendicular posts are placed between the tie-beam and the bow.

Underneath these are placed the transverse bearers, bolts passing through these, the tie-beam, the perpendiculars, and bow. On the bearers timbers are laid parallel to the truss, and on these the flooring of the bridge rests. This arrangement will be clearly understood on referring to the section (Fig. 55).

In commencing to copy this example, draw the horizontal line which forms the tops of the abutments, and then add the oblique lines representing the imposts.

Next draw another horizontal line, and between this and the last mark off the widths of the ends of the cross-timbers which act as wall-plates, on which the trusses are to rest.

This horizontal will also give the lower side of the saddle-pieces, and the horizontal which will give the top of these will also form the under side of the tie-beam, the upper side of which, and the ends of the saddle-pieces, may now be drawn.

The points at which the outer arc of the bow meets the upper line of the tie-beam are next to be marked, and the height of the bow set off on a central perpendicular. From these three points, the centre from which the arc is struck will be found in the manner already mentioned. The internal arc and the mortises at the ends will then complete the bow.

Having divided the space on each side into four equal parts by dotted perpendiculars, set off on each side of these half the thickness of the uprights, draw the ends of the bearers, the rail-bolts, etc.

The section is so very simple, that no further instruction connected with its delineation is deemed necessary.

It can be well understood that the system of forming the bow of a single timber must be limited to bridges of small span, and an improvement was effected in this respect by the introduction of a system invented by Philibert de Lorme, a celebrated French architect.

This system was not new, its author having proposed it in the sixteenth century, and it had been used more or less from that period; but it seems to have been first applied to bridges in that over the Weser, near Minden, in Westphalia, in the year 1800.

The De Lorme system will be fully described and illustrated in connection with "Roofs," in the construction of which it has been principally used; it may, however, be briefly stated here that it consists in building up the bow of separate pieces of timber placed *edge-wise*, and united in the manner called break-joint—that is, the joints in the pieces of each layer of timber composing the bow are alternated, so that those in the one are over the whole part of the other, nails and bolts passing through the complete thickness

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SEATS OF INDUSTRY.—III.

LIÉGE AND PITTSBURG.

BY H. R. FOX BOURNE.

If Birmingham and Sheffield vie with one another as the leading hardware towns of England, Liége is without a rival among the hardware towns of the continent of Europe, and Pittsburg has a like rank in America. The main features of these cities are interesting in themselves, and worth comparing with their English prototypes.

Liége is older as a town, though not as a hardware centre, than Sheffield or, perhaps, even Birmingham. There was a village of Legia in the seventh century; and the old cathedral, which was destroyed by the French revolutionary forces in 1794, was founded as early as the year 702. Its early history is chiefly ecclesiastical. In the tenth century its bishops became independent sovereigns, yielding feudal homage only to the kings of France; and even that was often refused. They had an influential position in mediæval Europe until Liége was captured by Charles the Bold in 1408, to be thenceforward annexed to Burgundy until it passed into the hands of the Spanish and Austrian monarchs, and ultimately became part of the new state of Belgium. Like all the other towns of that busy corner of Europe, it early applied itself to trade and commerce, and shared in the old prosperity of Ghent, Bruges, and Antwerp. It throve most after they had begun to decline. "Liége," it was written a hundred years ago, "is a very large and well-fortified city, on the left of the river Meuse, and contains a cathedral, seven collegiate and thirty parish churches; five abbeys for men, and a like number for women; thirty-two cloisters for both sexes, two colleges for Jesuits (now turned into seminaries), and ten hospitals; besides other charitable foundations. The manufactures here are very considerable, consisting of serges and other stuffs, all sorts of military weapons, nails and leather, and great numbers of brewers. There is pit-coal in its neighbourhood, with which they supply Holland very much."

That pit-coal has made the modern fortune of Liége. The wonderful coal-field, about six miles wide, stretching for a hundred miles from Mons to Liége, has seams as rich as any in the world, some of the pits being the deepest that are anywhere

worked. In the neighbourhood of Liége occupation is thus given to about 10,000 coal-miners; and the same district is rich in iron, besides yielding smaller supplies of zinc, lead, and copper. Thus the old city of bishops and churches has ready at hand an abundance of mineral wealth, put to good use by its thrifty inhabitants. The old fortifications have been well-nigh demolished; and the old streets—narrow, and often so steep that they are more like long flights of steps—are ill adapted for trading purposes; but trade flourishes. Though the town, which in the middle of the fifteenth century is reported to have contained a population of 120,000, now has only about 100,000 inhabitants, it has ten busy suburbs which share its occupation and contribute to its wealth.

Seraing, the chief of these suburbs, on the opposite side of the Meuse, and being to Liége what Southwark is to London, is the chief centre of the new life of the district. In it an old palace of the prince-bishops was, in 1817, converted into a great factory by an enterprising Englishman named John Cockerill. He followed the example of his countrymen at home, and began to use the coal and iron of the neighbourhood in making steam-engines and machinery of every sort. One of his first coke-blast furnaces was set up in 1823, and his establishment soon became, what it has ever since been, the largest of its kind on the Continent. King William I. took a great interest in the movement, and after a time, buying up the share of John Cockerill's brother, became a partner in it. Cockerill embarked in more than sixty other enterprises, in and out of Belgium, and was for a long period the greatest manufacturer out of England. His speculations brought him into some trouble, especially during the time of revolution; but he rode through all his difficulties, and his establishment was at the height of its prosperity during the few years previous to his death in 1840. After that it passed into the hands of a company known as the "Société de John Cockerill;" and the works now comprise a coal-mine, six blast-furnaces, a steel puddling-mill, an iron-foundry, and a general machine factory. Many kindred establishments have been founded, and by their energy Liége has been made the Birmingham of Belgium.

Liége is especially famous for its manufacture of cannon and fire-arms. The Royal Cannon Foundry, started in 1802, produces on an average nine large pieces of ordnance every week. The small arms are chiefly made by the workmen in their own houses; but the total produce is very large. It has more than quadrupled in the last fifty years, and is now much larger than that of Birmingham. In the ten years ending with 1864 there were made in Birmingham 5,611,000 guns; in Liége, 6,842,000. The estimated value of the English work, however, was about £10,500,000; that of the Belgian being only £8,200,000. The average price of an English gun is 32s., a government arm being twice as costly; that of a Belgian weapon is 24s. In the same ten years Liége produced 2,305,000 pocket-pistols, Birmingham only 588,000; yet the gross value of the latter rather exceeded that of the former. Most of the Belgian pistols cost only from one to two shillings a-piece. Vast numbers of these inferior weapons, as well as guns, are sold in this country and elsewhere at greatly enhanced prices, with counterfeited English trade-marks.

In the manufacture of fire-arms Liége cannot rival the excellence of Birmingham workmanship; but in rougher branches of the hardware trade there is successful competition, and Belgium, like France and Prussia, has the advantage over England in cheapness of labour and often in better training of the labourers. French ironworks are inconsiderable as compared with English; yet in them are adopted methods that England might well follow. "Some of the French mining manufacturers," said an English workman, describing the Paris Exhibition of 1867, "exhibited models, plans, and drawings not only of their works, but of schools, chapels, and workmen's dwellings, showing that they consider it in some measure a duty to attend to the social, moral, and intellectual condition of the workpeople; and from facts coming to our knowledge respecting the means of education supplied, the care taken of sick workmen, and the provision made for them in old age, it really does appear to us that the right steps are being taken by manufacturers for the purpose of surrounding themselves with intelligent and contented populations. This circumstance might possibly account to some extent for the fact that there is more economy in the use of fuel, and more care in utilising materials in connection with the ironworks in that country than in this. We saw no such plans or models in the English collections."

If Liége and the Continental iron towns differ in some important respects from those of England, there is yet greater difference in the case of the American towns, of which Pittsburg alone is considerable. Its history hardly covers more than a century; yet it has belonged to three nations. In February, 1754, the English, then engaged in fighting with the French and Indians, set up a stockade on the point at which the Alleghany and Monongahela join to form the river Ohio. In April they were driven out by the French, who chose the site for their Fort Duquesne, a famous centre of resistance to the English. Several attempts were made to regain it, and its conquest was effected in 1758. Fort Duquesne was replaced by Fort Pitt in 1759, and in 1764 the town of Pittsburg was begun. It was abandoned by the English in 1772, and then, after some years of rivalry between Virginia and Pennsylvania for its possession, it was assigned to the latter state. At that time the life of the United States was almost confined to their Atlantic coast-line. Save in traffic with the Indians for furs, there was but little done in the interior, and Pittsburg, though now reckoned one of the eastern towns of the country, was then one of the most western outposts of civilisation.

Its early growth was slow. Not till the Ohio and the Mississippi were found to furnish rare conveniences of transit between the northern and the southern states, and the splendid coal-fields of the district began to be recognised as the best source of fuel possessed by the country, was Pittsburg much thought of. The discovery once made, however, its later progress has been wonderfully rapid. In 1840 it contained 21,115 inhabitants; in 1850 the number amounted to 46,601; and in 1860 the town and its suburbs had a population of 115,000. "Compactly and well built," said one who visited it in 1848, "with wide streets, handsome squares and public gardens, it is thoroughly begrimed with smoke, and is certainly the darkest and dirtiest place I ever saw. Its great importance is due to its manufactories, for which it has every facility in the way of water-power and supplies of coal and iron; indeed, Pittsburg is a city of iron, hardware, and cutlery works. It annually manufactures large quantities of every kind of ironmongery, including steam-engines and machinery, cutlery and nails, and builds ships and steamboats on a large scale. It was a busy, grimy, sooty, dusty, coaly, dirty, Staffordshire-like kind of place."

The Pennsylvanian coal-fields cover an area of about 15,000 square miles, and are estimated to contain three times as much coal as all the fields of Great Britain—more than the whole of Europe. Most of the seams are easy of access, and there are excellent river facilities for concentrating the produce of the mines in Pittsburg, and thence dispatching it to all parts. More than a hundred collieries are within easy reach of the town. Ten or twelve are in its immediate vicinity; and these, giving employment to about 1,500 colliers, are known as the "City Mines," and feed the local manufactures. Of these manufactures, iron and steel are the most important. In 1860 Pittsburg contained twenty-three great establishments devoted to their production; the number of workmen so engaged being about 6,000, and the value of their produce about £2,500,000. It had also sixteen foundries; one for cannon—from which was sent out, in January, 1861, the famous "Union" gun, weighing 49,050 pounds. In 1860 the town produced about 350 steam-engines for ships and factories. It had two copper-mills, six cotton-mills, nine white-lead factories, and several establishments for constructing river steamboats.

The town may be considered to have about doubled in population and in trade between 1860 and 1870. Unlike most of the American towns, it gained instead of losing in the unfortunate war between North and South. A great impetus was given to its manufacture of large and small guns; and the Americans, who before that time went chiefly to Birmingham and Liége for their weapons, now have their wants supplied amply and more cheaply by Pittsburg. The town makes wonderful progress every year in all branches of hardware manufacture. Besides its abundant stores of coal, it has plenty of iron, copper, zinc, and lead in the neighbourhood; and by continuing to make good use of these advantages, it promises not only to hold its position as the chief hardware town in America, but also, in so doing, to surpass its rivals in the Old World.

PRINCIPLES OF DESIGN.—III.

By Christopher Dresser, Ph.D., F.L.S., etc.

TRUTH, BEAUTY, AND POWER IN ORNAMENTATION.

In my two previous chapters I have attempted to set forth some of the first principles of ornament, and to call attention to the purport or intention of certain of the leading historic styles, and the manner in which they make utterance to us of the faith or sentiments of their producers.

But there are other utterances of ornament, and other general expressions which decorative forms convey to the mind. Thus sharp, angular, or spiny forms are more or less exciting (Fig. 9); while bold and broad forms are soothing, or tend to give repose.

Sharp or angular forms, where combined in ornament, act upon the senses much as racy and pointed sayings do. Thus "cut" or angular glass, spinose metal-work, as the pointed foliation of some wrought-iron gates, and other works in which there is a prevalence of angles and points, so act upon the mind as to stimulate it, and thus produce an effect opposite to repose; while "breadth" of form and "largeness" of treatment induce tranquillity and meditation.

Nothing can be more important to the ornamentist than the scientific study of art. The metaphysical inquiry into cause and effect, as relating to decorative ideas, is very important—indeed, all-important—to the true decorator. He must constantly ask himself what effect such and such forms have upon the mind—which effects are soothing, which cheerful, which melancholy, which rich, which ethereal, which gorgeous, which solid, which graceful, which lovable, and so on; and in order to do this he must separate the various elements of ornamental composition, and consider these apart, so as to be sure that he is not mistaken as to what affects the mind in any particular manner, and he must then combine these elements in various proportions, and consider the effects of the various combinations on his own mind and that of others, and thus he will discover what will enable him to so act on the senses as to induce effects such as he may desire to produce.

Are we to decorate a dining-room, let the decoration give the sense of richness; a drawing-room, let it give cheerfulness; a library, let it give worth; a bedroom, repose; but glitter must never occur in large quantities, for that which excites can only be sparingly indulged in; for if it is too freely employed, it gives the sense of vulgarity.

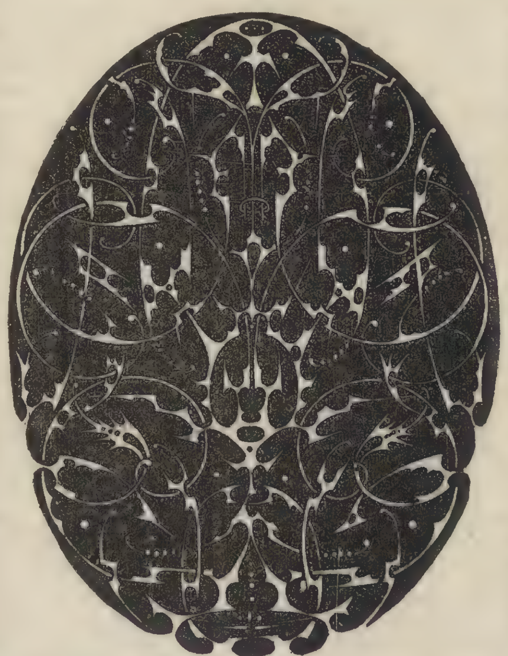


Fig. 9.—ORNAMENT COMPOSED OF SHARP AND SPINY FORMS.

In this chapter I have to speak primarily of *Truth*, *Beauty*, and *Power*. Long since I was so fully impressed with the idea that true art-principles are so perfectly manifested in these three words, that I embodied them in an ornamental device which I painted on my study door, so that all who entered might learn the principles which I sought to manifest in my works.

There can be morality or immorality in art, the utterance of truth or of falsehood; and by his art the ornamentist may exalt or debase a nation.

Truth.—How noble, how beautiful, how righteous to utter it; and how debasing is falsehood; yet we see falsehood preferred to truth—that which debases to that which exalts, in art as well as morals; and I fear that there is almost as much that is false, degrading, and untrue in my beautiful art as there is of the noble, righteous, and exalting, although art should only be practised by ennobling hands. It is this grovelling art, this so-called ornamentation, which tends to debase rather than exalt, to degrade rather than make noble, to foster a lie rather than utter truth, which brings about the abasement of our calling, and causes our art to fail in many instances in laying hold of, and clinging to, the affections of the noble and the great. Ornamentation is in the highest sense of the word a Fine Art; there is no art more noble, none more exalted. It can cheer the sorrowing; it can soothe the troubled; it can enhance the joys of those who make merry; it can inculcate the doctrine of truth; it can refine, elevate, purify, and point onward and upward to heaven and to God. It is a fine art, for it embodies and expresses the feelings of the soul of man—that inward spirit which was breathed by the Creator into the lifeless clay as the image of His life, however noble, pure, or holy.

This being the case, those who ignore decoration cast aside a source of refinement, and deprive themselves of what may induce their elevation in virtue and morals. Such a neglect on the part of those who can afford luxuries would be highly censurable were it not that the professors of the art are for the most part false pretenders, knowing not what they practise, and men ignorant of the powers which they hold in their hands. The true artist is a rare creature; he is often unknown, frequently misunderstood, or not understood at all, and is not unfrequently lost to a people that prefer shallowness to deep meaning, falsehood to truth, and glitter to repose.

We now see the utter folly of appealing simply to what is called "taste" in matters of art, and the uselessness of yielding to the caprice (falsely called taste) of the uneducated in such matters, especially as this so-called taste is often of the most vulgar and debased order. We also see the absurdity of persons who employ a true artist interfering with his judgment and ideas. The true artist is a noble teacher; shall he be told, then, what morals he shall inculcate, and what lofty truths he shall embody in his works, or omit from them? Do we tell the preacher what he shall say, and ask him to withhold whatever is refining and elevating? We do not, and in art we must leave the professors free to teach, and hold them responsible for their teachings.

If I thought that I had now convinced my reader that decorative art does not consist in the placing together forms merely, however beautiful they may be individually or collectively; nor in rendering objects simply what is called pretty; but that it is a power for good or evil; that it is what will elevate or debase—that which cannot be neutral in its tendency—I would advance to consider its principles; but I cannot teach, nor can I be understood, unless the reader *feels* that he who practises art wields a vast power, for the rightful use of which he must be held responsible.

All graining of wood is false, inasmuch as it attempts to deceive, the effort being made at causing one material to look like another which it is not. All "marbling" is false also: a floor-cloth made in imitation of carpet or matting is false; a Brussels carpet that imitates a Turkey carpet is false; so is a jug that imitates wicker-work, a printed fabric that imitates one which is woven, a gas-lamp that imitates an oil-lamp. These are all untruths in expression, and are, besides, vulgar absurdities which are the more lamentable, as the imitation is always less beautiful than the thing imitated; and as each material has the power of expressing beauty truthfully, thus truth has its own reward. A deal door is beautiful, but it will not keep clean; let it then be varnished. It is now preserved, and its own characteristic features are enhanced by the varnish, so that its individuality is emphasised, and no untruth is told. A floor-cloth can present a pattern with true and beautiful curves—how absurd, then, to try and imitate the dotty effect of a carpet; and the Brussels carpet can express truer curves than the Turkey carpet, then why imitate the latter? But perhaps the most senseless of all these absurdities is the

making an earthen jug in imitation of wicker-work, when if so formed it would be useless as a water-vessel. I can imagine a fool in his simplicity priding himself on such a bright thought as the production of a vessel of this kind, but I cannot imagine any rightly constituted mind producing or commending such an idea. Let the expression of our art ever be truthful.

Beauty. — I will say little on this head, for decorative forms must be beautiful. Shapes which are not beautiful are rarely decorative. I will not now attempt to express what character forms should have in order that they be considered beautiful, but will content myself by saying that they must be truthful in expression, and graceful, delicate, and refined in contour, manifesting no coarseness, vulgarity, or obtrusiveness of character. My views of the beautiful must be gathered from the series of articles which will follow, but this I may here say, that the beautiful manifests no want, no shortcoming. A composition that is beautiful must have no parts which can be taken from it and yet leave the remainder equally good or better. The perfectly beautiful is that which admits of no improvement. The beautiful is lovable, and, as that which is lovable, takes hold of the affections and clings to them, binding itself firmer and firmer to them as time rolls on. If an object is really beautiful we do not tire of it; fashion does not induce us to change it; the merely new does not displace it. It becomes as an old friend, more loved as its good qualities are better understood.

Power.—We now come to consider an art-element or principle of great importance, for if absent from any composition, feebleness or weakness is the result, the manifestation of which is not pleasant. Weakness is childish, it is infantine; power is manly—power is God-like. With what power do the plants burst from the earth in spring! With what power do the buds develop into branches! The powerful orator is a man to be admired, the powerful thinker a man we esteem. Even the simple power, or brute-force, of animals we involuntarily approve—the powerful tiger and the powerful horse call forth our commendation, for power is antagonistic to weakness. Power also manifests earnestness; power means energy; power implies a conqueror. Our compositions, then, must be powerful.

Fig. 10.—DESIGN EXEMPLIFYING POWER.

But besides all this, we, the professors of decorative art, must manifest power in our works, for we are teachers sent forth to instruct, and ennoble, and elevate our fellow-creatures. We shall not be believed if we do not utter our truths with power; let truth, then, be uttered with power, and in the form of beauty.

I have given in this chapter an original sketch (Fig. 10), in which I have sought to embody chiefly the one idea of power, energy, force, or vigour, as a dominant idea; and in order to do this, I have employed such lines as we see in the bursting buds of spring, when the energy of growth is at its maximum, and especially such as are to be seen in the spring growth of a luxuriant tropical vegetation; and I have also availed myself of those forms which we see in certain bones of birds which are associated with the organs of flight, and which give us an impression of great power, as well as those which we observe in the powerful propelling fins of certain species of fish.

VEGETABLE COMMERCIAL PRODUCTS.—IV.

PLANTS YIELDING SPICES AND CONDIMENTS (*continued*).

CARDAMOMS (*Elettaria cardamomum*, Maton; natural order, *Zingiberaceæ*).—Cardamom seeds are obtained from several other allied plants, but those of the above species of *Elettaria* constitute the true officinal Malabar cardamoms.

The cardamom is an obtusely triangular three-celled pod, about half an inch in length, of a pale-straw colour, and furrowed longitudinally on its outer surface. This pod contains numerous reddish-brown, rugose seeds, about the size of mustard seeds, internally white, and having a pleasant aromatic odour and an agreeable taste.

Cardamoms are principally employed here in medicine as a flavouring ingredient, and occasionally as a stimulant and carminative, especially in the form of a simple or compound tincture. In India they are much used as a favourite condiment for various kinds of food, as curries, ketchups, and soups. Their active principle is a pungent volatile oil.

Cardamoms are shipped to this country from Ceylon, the Malay peninsula, Sumatra, Java, Siam, Cochin-China, and the Malabar coast. The quantity of all kinds imported is about twenty-five tons per annum.

UMBELLIFEROUS PLANTS WITH AROMATIC FRUITS.

There are a few seeds which, from their pungent aromatic flavour, are used as condiments, and may very properly be classed with the spices.

The fruits of the caraway, coriander, and anise—called in commerce seeds—although cultivated in this country, are imported somewhat largely from the Continent, and are therefore deserving of notice.

CARAWAY (*Carum carui*, L.).—The caraway is indigenous to most parts of Europe, as well as to this country. It is cultivated to some extent in Essex and Kent. The taste of the seeds is aromatic and warm, and their odour is fragrant, but peculiar. The seeds are much used by the confectioner, and are sometimes added to bread; coated with sugar, they form the well-known "caraway comfits" to which children are so partial. We import about 500 tons of caraway seeds annually from Germany and Holland, nearly the whole of which are retained for home consumption.

CORIANDER (*Coriandrum sativum*, L.).—The fruit of this plant is globose, having a peculiar smell, and a pleasant, aromatic taste. In a fresh state both the fruit and foliage have an extremely disagreeable odour; nevertheless, the Tartars are said to use it in the preparation of a favourite soup.

The coriander is indigenous to Southern Europe and Italy, but has a wide geographical range, bearing the climate of India and Britain equally well. It is cultivated in this country, particularly in Suffolk and Essex, and is valued both by the apothecary and the distiller. Coriander is used in medicine for its carminative and aromatic properties, as a corrective to the griping qualities of cathartics. It is more used in confectionery than in medicine. Coriander-seed is also employed in adulterating beer. The poor Indian mixes these seeds with his curry, and they are equally welcome at the table of the rich. Our imports from Germany average fifty tons per annum

ANISE (*Pimpinella anisum*, L.).—This is a perennial plant, with an erect, round, striated, rough, or downy stem; pinnatisect leaves, white flowers, and an ovate, downy, aromatic fruit, resembling the finer kinds of parsley-seed in shape, and grateful and sweetish to the taste.

The oil of anise is obtained by distillation from the seed, about one cwt. of seed yielding two pounds of the oil. It is used in confectionery and in medicine. Anise is indigenous to Egypt, but is now largely grown in Malta, Spain, Italy, France, Germany, and the East Indies. The principal imports are from Alicant in Spain, and Hamburg in Germany, and average about seventy tons per annum.

Other umbelliferous plants used as condiments are cumin (*Cuminum cymium*, L.) and angelica (*Archangelica officinalis*, Hoffm.).

STAR ANISE (*Illicium anisatum*; natural order, *Magnoliaceæ*).—This plant is so called because the flavour of aniseed pervades the whole of it, especially the fruit; but it is not at all allied to anise, belonging to a totally different natural order. It is a shrub indigenous to China and Japan: its fruit is used to flavour sweetmeats, confectionery, and liquors. The aromatic oil of star anise, singularly enough, in every respect resembles anise oil, for which it is often substituted. In India, star anise is an important article of commerce, and sold in all the bazaars.

MUSTARD.—The seeds of *Sinapis nigra*, L., often mixed with *S. alba* (natural order, *Cruciferæ*).—The spherical seeds of these two species are crushed, pounded, and then sifted through a fine sieve; the fine, powdery product is the "flour of mustard" in common use. The outer skin of the seeds, separated by sifting, forms a coarse powder, which is sold for adulterating pepper. Mustard-seed is largely imported from the East Indies for the expression of oil; and white-mustard seed is imported from Northern Germany, in small quantities, for grinding with the black mustard-seed grown in this country.

IV. PLANTS YIELDING SUGAR.

SUGAR-CANE (*Saccharum officinarum*, L.; natural order, *Gramineæ*).—This plant, next to rice and maize, is the most valuable of the tropical grasses. Its stem, which is solid, cylindrical, and jointed, is two inches in diameter, and from twelve to fifteen feet in height; its leaves are long, narrow, and drooping; flowers very handsome, appearing like a plume of white feathers, tinged with lilac. A field of sugar-canes in blossom presents a very beautiful appearance.

The sugar-cane is seldom permitted to flower under cultivation. It is propagated by sections of the culm, or stem, with buds in them. Trenches are cut, and the pieces of the culm are laid horizontally in them; the earth is then thrown into the trench, and the canes soon develop from the nodes or joints of the culm. As they grow up, and the wind gains power over them, the lower leaves are removed, and the stems are strengthened by being fastened to bamboo supports.

The sugar-cane plant is very sensitive to cold, and therefore its cultivation is restricted to the tropics, and to regions on their borders where there is little or no frost. In the Old World sugar plantations are mostly confined to countries lying between the 40th parallel of north latitude and a corresponding degree south; in America, along the Atlantic seaboard, they do not thrive beyond 33° north latitude and 35° south latitude; whilst on the Pacific side the sugar-cane matures about 5° further to the north and south of the equator. The principal countries where sugar is largely grown are the West Indies, Venezuela, Brazil, Mauritius, British India, China, Japan, the Sunda, Philippine, and Sandwich Islands, and the Southern United States of America. Moreton Bay and the northern parts of Australia are admirably suited, both in soil and climate, to sugar culture.

Manufacture of Sugar.—When the cane is ripe, it is cut down, deprived of its top and leaves, cut up into convenient lengths, tied up in bundles, and taken to the mill. Here the canes are crushed between iron rollers, the juice from them flowing into vessels, where it is boiled with the addition of lime, and evaporated to the consistence of syrup, care being taken to remove any scum which appears on the surface during this part of the process. The lime is added to remove any acidity, and prevent fermentation. The material of the fire consists of the refuse crushed cane, dried for that purpose in the sun. Six or eight pounds of cane-juice will yield one pound of raw sugar; and from sixteen to twenty cart-loads of cane ought to make a hogshead of sugar, when thoroughly ripe. The cane syrup thus prepared is transferred to shallow vessels, or coolers, in which it is stirred until it becomes granulated; it is then put into hogsheads having holes in the bottom, which are placed in an upright position over a large cistern, and allowed to drain. In this state it is called muscovado or brown sugar, and the drainings molasses. The casks are then headed down and shipped. This muscovado is purchased by the grocers, and constitutes the brown or moist sugar of the shops.

The planters in the West Indies generally send their sugar to England in the form of muscovado; but in the French, Spanish, and Portuguese settlements, it is usually converted into clayed sugar before exportation. The process is as follows:—The sugar from the coolers is placed in conical pots with holes at the bottom, having their points downward. A quantity of clay is laid on the top and kept moistened with water, which, oozing gently from the clay through the sugar, dilutes the molasses, and causes more of it to come away than in the hogshead, leaving it whiter and purer than the muscovado sugar.

Loaf or refined sugar is made from the muscovado by the sugar-bakers in England. The muscovado is re-boiled, and refined with the serum of bullock's blood or the white of eggs; it is then transferred to conical moulds, and clayed repeatedly until perfectly white. The sugar is then removed from the moulds, and set in a stove to dry.

The sugar-cane, a plant originally confined to Asia, and which grew wild in India, was introduced into the south of Europe from the East by the Saracens, soon after their conquests in the ninth century. In the twelfth century, sugar plantations were established in Cyprus, Rhodes, Candia, Malta, Sicily, and Spain; and as early as the beginning of the fifteenth century they had been extended to Granada, Murcia, Portugal, Madeira, and the Canary Islands.

The sugar-cane is now cultivated at only a few places in Europe, viz., Malta, Sicily, and the south of Spain. The rest of the sugar plantations have disappeared from the countries about the Mediterranean, in consequence of the extent of the great American plantations, and those in the West Indies.

In the middle of the sixteenth century the sugar-cane was transplanted by the Portuguese to Brazil, and by the Spaniards to the West Indies, where the greatest quantity of sugar is now produced. Brazil has now 900 sugar plantations, producing annually about 50,000 tons of sugar; and of the West India Islands, Cuba and Jamaica alone raise 150,000 tons for exportation yearly. Porto-Rico, and the French, Dutch, and Danish colonies in the West Indies, export sugar largely, as do also Louisiana and Alabama, by way of New Orleans. The exports of sugar from Mexico go mostly to New Granada, Caracas, and Ecuador in South America.

The East Indies, Java, Sumatra, the Philippine Islands, Siam, Cochin-China, Bengal, and Ceylon, all produce sugar for exportation. Sugar has been made in China, indeed, from very remote antiquity, and large quantities also have been exported from India in all ages.

In 1866, 10,639,085 cwt. of raw sugar were imported into the United Kingdom, of which 5,823,729 cwt. were received from our colonies, and the rest from foreign countries. Of this amount 10,297,196 cwt. were retained for home consumption, and the remainder exported.

Rum, or Brandy of Sugar.—The best is distilled from the pure juice of sugar; the inferior kind is made from treacle, and from the residuum in the sugar refineries. Jamaica rum is the finest, about three millions of gallons being annually imported into England from the West Indies. Rum is also distilled for exportation in Bengal, Madras, Batavia, and Manilla. The native arrack of India has been nearly driven out of the market by this spirit.

Besides the sugar-cane, many other plants yield sugar. The principal of these are :—

1. Beet-root and Mangold-wurtzel (two varieties of *Beta vulgaris*, Tournef; natural order, *Chenopodiaceæ*) are cultivated very extensively on the continent of Europe, especially in France, where a great portion of the supply of sugar is obtained from the juice of these sap-roots. In Great Britain beet-root is eaten as a salad, and mangold-wurtzel is largely grown as winter food for cattle.

2. Sugar-maple (*Acer saccharinum*, Wang.; natural order, *Aceraceæ*).—From the juice which flows from incisions made in the stem of this, and probably other species of maple, large quantities of a coarse uncrystallisable sugar are manufactured in North America.

3. Date (*Phœnix dactylifera*, L.; natural order, *Palmaceæ*).—From this useful palm, and also from *P. sylvestris*, L., and *Saguerus saccharifer*, sugar is produced by boiling the juice, which flows from incisions made in the flower-heads; from *P. sylvestris*, L., alone, as much as 6,000 tons are made annually. These sugars are mostly consumed in India; much, however, is supposed to be imported to this country as cane sugar. The fruit of the date is well known and highly appreciated in this country. It is remarkable for its nutritious and life-sustaining qualities; the Arabs, while crossing vast desert tracts, requiring no other food than a handful or two of this fruit per day. The best grow in the regions on the southern slopes of the Atlas mountains. This part of Africa is said to be the natural habitat of the date-palm, and is called *Bil-ed-ul-jerid*, or the Date Country.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—II.

It has been explained in previous lessons that "to bisect" means to cut into two equal portions; this requires to be properly understood in dividing angles, for it will be evident that if a line were drawn *across* the angle, the one part would be much wider than the other, even though the line might cross exactly in the middle of one of the lines forming the angle. The following problem shows the correct method of overcoming the difficulty, and subsequent figures show the application of the lesson.

To bisect an angle, A B C (Fig. 8).—From B, with any radius,

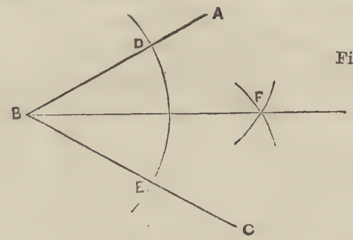


Fig. 8.

describe an arc, cutting the lines B A and B C in D and E.

From D and E, with any radius, describe arcs cutting each other in F.

Draw B F, which will bisect the angle.

To inscribe a circle in the triangle A B C (Fig. 9).—Bisect any two of the angles (by Fig. 8).

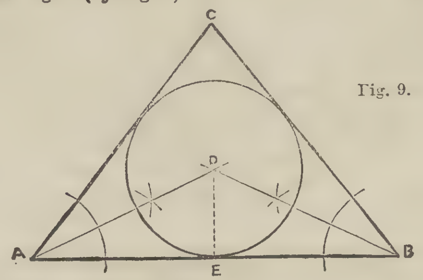


Fig. 9.

Produce the bisecting lines until they meet in D.

From D, with the radius D E, which is a perpendicular from D on A B, a circle may be described which will touch all three *sides* of the triangle. This is called the *inscribed* circle.

To draw a circle through three points, however they may be placed, provided they are not in an absolutely straight line (Fig. 10).

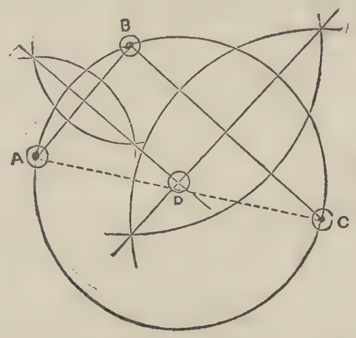


Fig. 10.

Let A B and C be the three given points. Join A B and B C. Bisect A B and B C, and produce the bisecting lines until they cut each other in the point D.

Then D will be equally distant from each of the three points. Therefore, from D, with radius D A, D B, or D C, a circle may be drawn which will pass through the three given points.

It will be evident that if A and C were joined, the figure would be a triangle; and thus this problem serves also for describing a circle which shall touch the three *angles* of a triangle. This is called the *circumscribing* circle.

The Gothic trefoil (Fig. 11).—The trefoil is a figure much used in Gothic architecture. It is formed of three leaves, or lobes (hence its name), meeting at a centre, as in the three-leaved clover. It is sometimes enclosed in a circle, as in window tracery, but not always, as in many wall-piercings. This figure will serve as an application of the construction of the equilateral triangle and the bisecting of angles. It is here introduced with the view of showing students the importance of *absolute* accuracy in the early problems, as well as in the subsequent operations.

Construct an equilateral triangle, *a b c*.

Bisect the angles, and produce the bisecting lines, *d*, *e*, *f*.

Observe, that in an equilateral triangle, the lines which

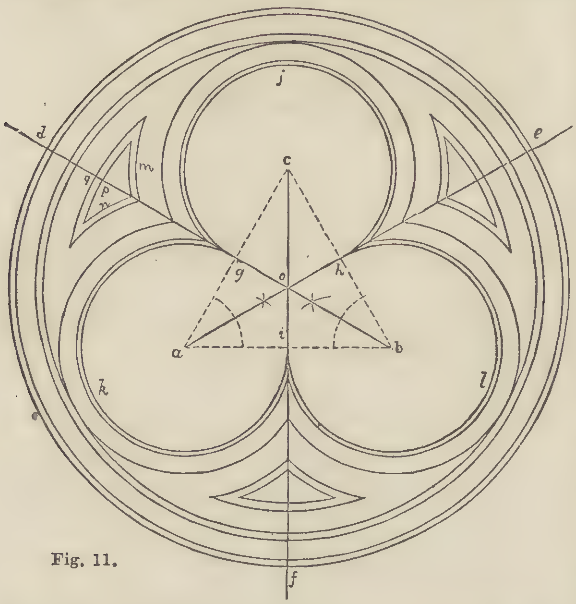


Fig. 11.

bisect the *angles* will, if produced, bisect the *sides* opposite to the angles as well, and thus the points *g*, *h*, *i* are obtained.

From *a*, *b*, and *c*, with radius *a g*, equal to half the side of the triangle, describe the arcs *j*, *k*, *l*, and the others, which it will be plain are concentric (that is, drawn from the same centre) with them. The arcs *m* and *n*, and those corresponding to them, are also drawn from the same centres.

The outer circles and the arcs *p*, *q*, etc., are drawn from the centre of the triangle *o*.

To construct on the given line, D E, *an angle similar to the angle* A B C (Fig. 12).

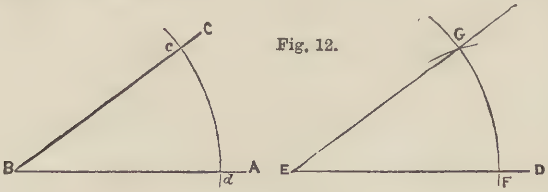


Fig. 12.

From B, with any radius, describe an arc cutting the sides of the angle in *c d*.

From E, with the same radius, describe an arc, cutting E D in F. Measure the length from point *c* to *d*. Mark off the same on the arc from F—viz., to point G. Draw a line from E through G. The angle F E G will be equal to A B C.

On the given line, A B, *to construct a triangle similar** to C D E (Figs. 13 and 14).—At A construct an angle similar to the angle H C G—viz., J A I.

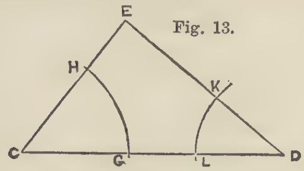


Fig. 13.

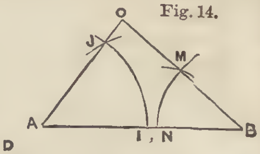


Fig. 14.

At B construct an angle similar to the angle K D L—viz., M B N. Produce the lines A J and B M until they meet in O; which will complete the triangle required.

Definitions concerning four-sided figures which are not parallelograms.—A figure having four sides, which are neither equal

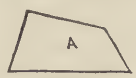


Fig. 15.

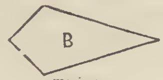


Fig. 16.

Fig. 17.

nor parallel to each other, is called a *trapezium*, as A (Fig. 15).

But any two of its adjacent (or adjoining) sides may be equal to each other, so long as they are not parallel to the opposite sides, as B (Fig. 16).

If any two of the sides are parallel to each other, the figure is called a *trapezoid*, as C (Fig. 17).

To construct a trapezium similar and equal to another, C D E F (Figs. 18 and 19).

Draw A B equal to C D.

At A construct an angle similar to that at C.

Make A G equal to C E.

At B construct an angle similar to that at D.

Make B H equal to D F.

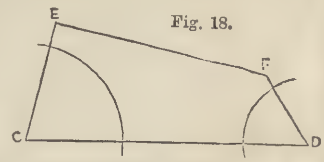


Fig. 18.

Join H G, and the trapezium on A B will be similar and equal to C D E F.

It is advisable that the students should be repeatedly exercised in constructing figures similar and equal to each other; and as the correct result of the higher figures depends on the refinement of their construction, the most *intense accuracy* should, from the very outset, be aimed at.

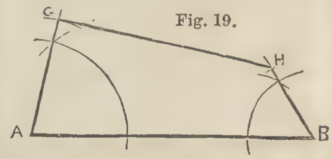


Fig. 19.

Having thus illustrated the difference between the trapezium and the trapezoid, and between similar and equal, we now proceed to construct these figures similar to others, and of given dimensions. The artisan cannot too soon begin to work to "scale," and he is therefore recommended to take the measurements from his rule, not from these pages; the result must be the same, even though the mere sizes may be different.

To construct on the given diagonal, A B (Fig. 20), *a trapezium similar to another*, C E D F (Fig. 21).

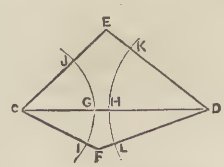


Fig. 20.

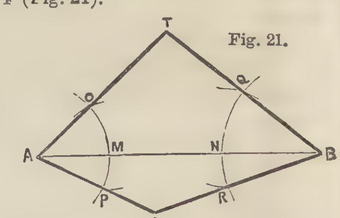


Fig. 21.

Draw the diagonal C D in the given trapezium. From C and D, with any radius, draw arcs cutting the diagonal C D in G and H, C F and C E in I and J, and D E and D F in K and L. From A and B, with the same radius, describe arcs cutting the diagonal A B in M and N. From the point M, cut off on the arc the length G J—viz., to O, and also the length G I—viz., to P. From the point N, cut off on the arc the length H K—viz., to Q, and also the length H L—viz., to R.

Draw B Q and B R; also A O and A P. Produce these lines until they meet in S and T. A T B S will be the trapezium required.

* When a figure is said to be *similar* to another, it means that it is of the same *shape*. When it is said to be *equal*, it means that it is of the same area—that is, it contains precisely the same *space*. A figure may be equal to another without being similar in shape: thus a square may be equal in area to a rectangle; and a figure may be *similar* without being *equal*, as in Figs. 13, 14. "*Similar and equal*" means being of both the same *shape* and *size* as another figure, as in Figs. 18 and 19

This result would be the same, whatever might be the length of the diagonal or the relative sizes of the figures, as an angle is not altered by the length of the lines of which it may be formed.

To construct a trapezium from the following given dimensions (Fig. 22).—Sides C A and C B are to be adjacent to each other, forming an angle similar to A B C. C A is to be $1\frac{3}{4}$ inches long; C B, $1\frac{1}{2}$ in.; A D, 1 in.; B D, $1\frac{1}{4}$ in.

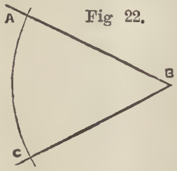


Fig 22.

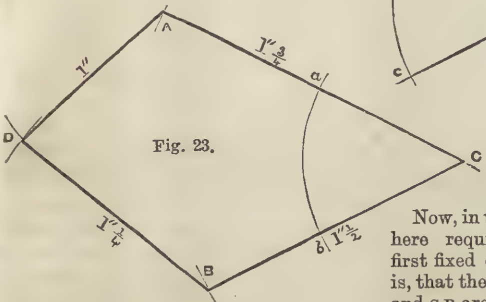


Fig. 23.

Now, in the figure here required, the first fixed condition is, that the sides C A and C B are to make an angle similar to the given angle A B C. Therefore at any point, construct this angle (a C b), and produce the lines until C A is $1\frac{3}{4}$ inches, and C B $1\frac{1}{2}$ inches long—viz., to A and B.

From A, with 1 inch radius, describe an arc. From B, with $1\frac{1}{4}$ inch radius, describe another arc cutting the former in D. Draw A D and B D, which will complete Fig. 23 from the given dimensions.

COLOUR.—II.

By Professor CHURCH, Royal Agricultural College, Cirencester.

COMPOSITION OF LIGHT—COMPLEMENTARY COLOURS—THE SPECTRUM.

IT was Newton who first discovered the compound nature of white light. In order to split up a ray of the solar light into its constituent parts, the following contrivance (Fig. 1) may be adopted:—Through a hole in the shutter of a darkened room a beam of light, S, is allowed to enter. This small beam must fall upon a prism of flint-glass, A, so arranged that the side, P, opposite to its refracting angle is uppermost and horizontal. The beam will be refracted and dispersed, as described in our last paper; and if the refracting angle of the prism be 60°, a vertical

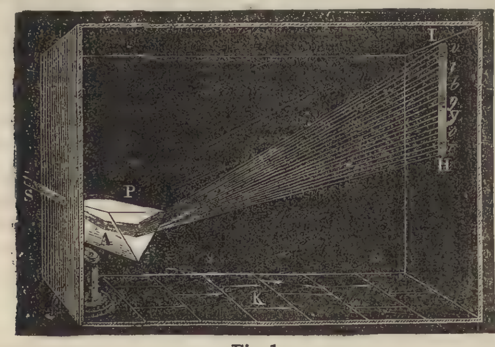


Fig. 1.

band of rainbow colours will be produced on a screen placed at a distance of five yards or so from the prism, A. This band, H I, is the solar spectrum. It consists of a very large number of different tints, amongst which it is easy to distinguish seven principal colours. Beginning at the end of the spectrum which is nearest to the spot, K, the beam would have reached had no prism bent it out of its path, we find the order of the colours is as follows:—Red, orange, yellow, green, blue, indigo, violet. Now the mode in which these colours have been separated from white light is sufficient proof that they cannot be further separated into other kinds of colour. This anticipation is realised by actual trial; for if, as in Fig. 2, one of the colours of the spectrum, v, be allowed to pass through a hole in the screen, E, on which the band of decomposed light has been received, it cannot be altered by being transmitted through a second prism, B. The ray will be refracted, of course, but it will show but one colour, as before, and its image will not be elongated.

We have already learnt that every ray of coloured light has its own wave-length, and therefore that all the colours of the spectrum, however similar they may seem, are really distinct tints. But this consideration does not take in all the facts of the case. The green of the solar spectrum is not compound, but simple; and yet we know that many substances of a green colour may be split into two components, one blue and the other yellow. Supposing for a moment we can exactly imitate the

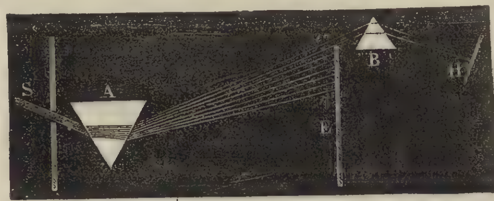


Fig. 2.

green of the solar spectrum by mixing yellow and blue pigments together, this fact would not of itself suffice to prove that the solar green was really a mixed hue; but it would show that the sensation of vision is similarly excited by the waves that reach the eye from these two colours—one simple, the other apparently compound. Precisely the converse of this holds good. We can, as might be expected, re-form white light by re-uniting all the seven dispersed coloured lights of the solar spectrum (we will describe how to do this presently); but we can reach the same result by re-uniting merely certain pairs of these coloured lights. Thus, the following unions of two colours generate white, or nearly white light:—

1. Red—greenish-blue.
2. Orange—Prussian-blue.
3. Yellow—indigo-blue.
4. Greenish-yellow—violet.

These pairs of colours, and many others less easy to distinguish by intelligible names, when united lose their respective colours and become white. They are called *complementary* colours. It will be seen that we have followed in our grouping of them the sequence of the colours of the spectrum, beginning with the red or least refrangible rays; but in order to produce white light by the combination of any couple of the above colours, two conditions must be fulfilled—the intensity and the quantity of the component rays must be adjusted with care. By receiving two such coloured pencils of light upon a lens which condenses and brings them to the same focus on a white screen placed at a suitable distance, the result is a perfectly white light; but, to secure this result, the constituents of a coloured ray are as important as its apparent quality of colour. Thus Helmholtz has found that the red and bluish-green of the spectrum produce yellow, not white; while red, with the bluish-green formed by the union of green and indigo, does yield white. Green and red have indeed a relation to each other which is different in some particulars from that of many other pairs of colours. They, however, are often included among the pairs of so-called *complementary* colours for reasons to be hereafter noticed. That there is something very peculiar in the relation of green to red may be also concluded from the frequency with which these two colours are confounded by persons who suffer from colour-blindness or Daltonism.

One of the most curious of all the results of studying the re-composition of white light is the relation of yellow to blue. It is a matter of observation that a yellow and blue liquid and a yellow and blue powder, when mixed together, produce respectively a green liquid and a green powder. But a very different result ensues on mixing blue and yellow light together. When the blue and yellow rays of the spectrum are mixed together, white light is produced. The same effect results from receiving upon the eye the reflected image of a disc painted with gamboge along with the direct image of a second disc painted with cobalt-blue. Though a disc painted with these two pigments mixed together would have appeared green, yet when the lights these pigments respectively reflect are conveyed to the retina as above described, then, where the two images coincide, whiteness is the result.

We must now describe some of the peculiarities of different spectra, and afterwards a few of the more recondite methods by which colour is produced.

Our purest source of coloured lights is a spectrum. We may use the spectrum of the solar beams, or that from the electric lamp: the latter is more convenient, and yields, as we have previously stated, a light more complex than the sun; for in the solar spectrum there are some three thousand or more gaps where rays are missing. These are the black lines first noticed by Wollaston, in 1802, afterwards mapped out by Fraunhofer, and at last explained by Bunsen and Kirchhoff. These black lines indicate lost rays—rays which have been blotted out by absorption. The absorption takes place in the following manner:—In the sun's gaseous envelope certain vapours exist. These vapours are opaque to certain rays of light: they do not allow them to pass, but quench them. There is, for instance, the metal sodium in the sun's gaseous covering. Now sodium vapour is opaque to a certain yellow ray which it itself originates when it is burnt. Consequently, the place which should be occupied by a bright yellow band in the solar spectrum is a dark line, or rather group of lines, called D. In like manner the other black lines, or many of them, have been traced to the special absorptive powers possessed by the sun's gaseous envelope, and exercised upon certain rays of light emanating from within. These black lines, however, in the solar spectrum, though rendering it imperfect in continuity, are of great service in referring to the localities of particular colours. Yet we must not forget that the material of the prism exercises some influence upon the position of the lines and the relative extent of the coloured bands. With a future part a coloured plate will be given in which will be shown the positions occupied by the most important of the black lines and coloured spaces in the solar spectrum when obtained by means of a flint-glass prism in the spectroscope. The conditions of success in obtaining these lines distinctly are a narrow, clean-edged slit, a collimating lens to make the luminous rays parallel, and a prism of highly-refractive and dispersive glass, quite free from striæ and flaws. The instruments known as spectroscopes are, however, always of more complicated construction than these conditions seem to involve; for it is desirable to use a battery of prisms instead of one prism, and to obtain a magnified image of the spectrum by means of a combination of lenses in a telescope. Let us turn now to the consideration of the spectra as obtained by means of the spectroscope.

Most of our sources of artificial light yield spectra without lines. An oil-lamp, gas-flame, the electric light, are instances of this kind. But it is easy to secure a flame which shall yield a very simple spectrum, reduced by the absence of so large a number of rays that it shall merely consist of a few bright bands, or merely of one. Dissolve a little common salt, for instance, in some methylated spirit of wine, and introduce the solution into a spirit-lamp. The flame will, to the eye, appear tolerably luminous and distinctly yellow. The spectrum of this flame shows little more than a single brilliant yellow band, occupying the dark space of the solar spectrum called D. The metal sodium is distinguished from other metals by its flame emitting rays of that particular refrangibility only. If a salt of lithium be taken, and dissolved in spirit, the flame of the lamp will be crimson, and two coloured bands will characterise the spectrum. One of them is red, and very distinct; the other is of a faint orange tint. Other metals produce different spectra, though in many cases the colour which they impart to the flame of a Bunsen gas-burner or a spirit-lamp may seem to the unassisted eye identical.

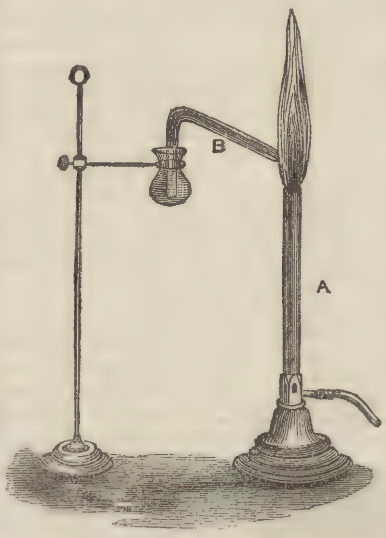


Fig. 3.

In trying experiments with coloured flames, in order to study their effects on the appearance of different objects, the following contrivance may be used:—A (Fig. 3) is a Bunsen gas-burner (which is best made of steatite); B is a bundle of fine platinum wires, dipping into a small vessel containing a mixture of a solution of the metallic salt to be experimented with, and ammonium chloride. A ball of pumice attached to a bundle of asbestos fibres may be substituted for the platinum wires. The following is a list of substances which give colours of different hues to the flame of a burner under the circumstances described, the metallic salts most applicable being those known as chlorides, chlorates, and nitrates:—

Substances.	*Colours of Flame.*
Calcium nitrate	Red.
Lithium chloride	Carmine.
Strontium nitrate or chlorate	Crimson.
Sodium chloride	Yellow.
Barium chloride or chlorate	Yellowish-green.
Boracic acid	Green.
Thallium perchloride	Green.
Copper chloride	Bluish-green.
Indium chloride	Indigo-blue.
Potassium chlorate	Violet.

The above substances give, for the most part, spectra with many bright lines of different colours; but the red lines will dominate in one spectrum, and the green in another.

Thus far we have been studying light and colour by means of the prism: we will now see how the colours of the spectrum may be separated without that instrument, and yet without loss of any of their component parts. Some of the most beautiful phenomena of colour are produced by a modification which light undergoes when it passes the edge of an opaque body, or when it traverses a small opening. Light then turns a corner. This bending of the waves of light has been termed *diffraction*. The source of light in studying the phenomena of diffraction should be a luminous or highly illuminated point. A silvered bead, or steel globule, or the focus of rays obtained by the action of a lens on a beam of light entering a dark chamber by means of a small hole—all these contrivances furnish a suitable light. If a narrow rectangular slit between two metallic edges be placed in a beam of light, between the focus of a lens and a screen, the space between the edges will be occupied by bands of coloured light. If one colour only be used, as by the interposition of a screen of red glass, then alternate bands of that colour and black will be seen. By using, instead of a simple rectangular slit, apertures differing in size, number, and shape, very beautiful chromatic appearances may be developed. These may be obtained by looking at a bright point or line of light through a bird's feather mounted in a card-frame, through a piece of glass dusted with lycopodium spores, through a fine wire-grating, through a piece of very fine cambric, or through a plate of smoked glass ruled with fine lines.

The halo of colours sometimes seen round the moon and the sun is a phenomenon of the same kind, produced by the diffraction of light by the globules of water constituting the fog. Imperfectly polished metals, the feathers of many birds, and the surfaces of mother-of-pearl, owe part, at least, of the peculiar coloured effects which they exhibit, and which are known as iridescence, to the diffraction of the light reflected from the small striæ, filaments, or folds of their surfaces.

Now, without entering into the minute particulars necessary to elucidate these appearances thoroughly, we may state that the phenomena of diffraction are due to two causes. One of these is the bending of light round a corner, as waves of water bend round a rock in a lake; the other, the interference of the waves of the light-rays so bent with one another. Interference of one set of oscillations with those of another set may even extinguish the light altogether. This takes place when the crests of the undulations of a ray coincide with the hollows of the undulations of another ray: thus there will be rays on either side of a slit which, bent by diffraction, will by this kind of interference exactly neutralise each other and abolish the light.

The dark bands and lines produced by diffraction are explicable in this way. As to the cause of the colours seen under the conditions just mentioned we may refer to the

obliquity of the paths of the diffracted rays. If red light be employed, black and red rings or bars alternate; but with violet light, black and violet rings or bars are seen. The violet rings are nearer together than the red, because their waves are smaller than the red. We can obtain bands of colours intermediate in width between red and violet by employing, for example, green light. Hence, when *white* light passes through a slit, we obtain a series of coloured spectra side by side, because the constituent colours are not superposed, owing to the obliquity of the paths of the rays and their different wave-lengths. More or less obliquity in the path of a diffracted ray will cause it to differ, by various parts of a wave-length, from other diffracted rays of the same beam.

The colours of thin plates correspond in sequence, as do those of diffraction, to the colours of the prismatic spectrum. They are produced by the interference of the ray which enters the thin transparent film, and is reflected from its second surface, with the ray which is directly reflected from its first surface. A soap-bubble may be of such a thickness as to retard the beam reflected from its second surface by half a wave-length, or by any number of half wave-lengths. Then it will be found that the bubble is black, because the two reflected beams are in complete discordance; and a destruction of light follows. Then, again, soap-bubbles may vary very much in the thickness of different parts. As the waves of light differ in length, so they will require different thicknesses to produce accordance and discordance. The result of this is that a thickness of film which is competent to extinguish one colour will not extinguish other colours. Thin films of variable and changing thicknesses, illuminated by white light, will therefore display in their different parts variable and changing colours. The colours of the precious opal are due to the interference of the internal reflections from its minute vacuous fissures. The colours of tar-films upon water, of many insects' wings, and of lead-skimmings, are due also to interference. So also are the splendid chromatic appearances of certain crystals when viewed in polarised light, and, to some extent also, the colours previously alluded to as iridescent.

We will next turn our attention to the production of colour by "selective absorption," to the re-composition of white light by the re-union of its scattered elements, and then to the mutual relations of those coloured elements.

THE ELECTRIC TELEGRAPH.—II.

By J. M. Wigner, B.A.

INSULATORS (*continued*)—TESTING THEM—MODE OF MAKING JOINTS—LIGHTNING CONDUCTORS—COVERED WIRE—MODE OF MAKING JOINTS IN IT.

However perfect the insulators employed on any line may be, there is sure to be some slight escape of the current, and our care is to reduce this to a minimum. Dust and dirt settle on the insulators, especially when they are damp, and thus allow some portion of the electricity to escape to the post. Formerly a screen was placed over the insulator, to shield it from the rain; but it is now found that when there is a good glaze to the earthenware, the rain washes off the dirt, so that after long-continued dry weather a smart shower will frequently materially improve the insulation of a long line: the screen is consequently dispensed with.

Glass and different glazes also condense the moisture of the air on their surfaces, and thus produce a damp layer, by which the current escapes. In this respect ebonite is found to be superior to any substance of a vitreous nature, but at present its durability and economy have not been sufficiently tested, and it is but little adopted for general purposes. When, through defective insulators, or in any other way, the current leaks to the ground, the line is said to be "earthy," and usually the defect may be remedied by an increase of the battery power. If a full contact is made with the ground, so that the whole or the greater portion of the current is lost, there is said to be "dead earth."

Very frequently a portion of the current leaks from one wire to another, and in this way the messages along both lines are rendered more or less indistinct. There is then said to be "contact." Spiders' webs round the wires will, when they become damp, act thus, and where the lines cross public streets, they are frequently fouled by the strings of kites. These strings becoming broken in the attempts made to save the kite, get twisted round the wires, and in damp weather greatly interfere with the communication.

In earthenware insulators cracks are not unfrequently produced by the unequal shrinking of the wire in drying or baking, and if these are covered with a glaze they may escape detection at first. After a while, however, the glaze cracks, and then the flaw becomes apparent by the escape of the current. A good glaze is useful, since it hinders the adherence of dirt and dust, but it must not be depended upon as an insulator.

All insulators should, before being employed, be carefully tested, so that defective ones may be rejected. This is usually done by immersing the porcelain or earthenware portion for a few hours in dilute sulphuric acid, or in salt and water. One pole of a battery is then applied to the stalk of the insulator, and the other is immersed in the liquid, a delicate galvanometer being introduced into the circuit, and in this way a flaw is easily detected. In a few cases a portion of the glaze is removed, so as to test the quality of the ware itself.

On a very wet day it is often found difficult to communicate with distant stations on account of "weather contact," or the leakage of the current along the insulators and posts. In such a case it is frequently found very advantageous to join a fresh set of batteries side by side with the others, so as to increase the quantity rather than the intensity. Two batteries thus joined side by side are, of course, equivalent to one having cells double the size.

The following experiments tried by Mr. Walker, of the South-Eastern Railway, illustrate this well. The figures in the last column indicate the strength of the current received at the further end, as shown by a quantity galvanometer. The line was a defective portion, five or six miles long:—

Cells.	*Size.*	*Strength.*	*Cells.*	*Size.*	*Strength.*
24	Ordinary	10	48	Double	37
24	Double	24	72	Ordinary	21
24	Treble	27	72	Double	43
24	Sixfold	32	96	Ordinary	23
48	Ordinary	19			

From this it will be seen that a greater power was obtained from forty-eight cells connected in pairs (twenty-four double cells) than from ninety-six connected in the ordinary way.

In many of the telegraph wires that cross the roofs of houses in large towns, a form of insulator different from any hitherto described is employed. It consists of a short cylinder of porcelain (Fig. 5), with a hole pierced along its centre, and a broad groove round it, so that it somewhat resembles a short and stout reel. The wire is then passed round the groove, and fastened off as at an ordinary terminal insulator. Another wire is passed through the central hole, and by this it is affixed to the post. The wire at the other side of the post is fastened in a similar way, so that two insulators are required at every post. As, however, they are of a very simple form, consisting merely of a lump of porcelain, their cost is but small. A short link of wire is connected beyond the insulators on each side, and forms the passage along which the electric current passes. This plan is found much more simple and economical for carrying the wires over houses. If any wire breaks, only the length between the two posts is affected, and can easily be repaired; it is also easier to stretch the wires when fastened in this way.

Wire cannot easily be obtained in lengths of more than about a thousand yards, and usually it is made in shorter pieces; frequent joints have, therefore, to be made, and the manner of making these is a thing of very great importance. It is not sufficient merely to make a strong joint, which shall bear the strain: we must also ensure a complete electrical contact; and as, after a while, the wire becomes more or less oxidised, great care is necessary, or else in a short time the current would be seriously impeded, or even altogether interrupted. The joint most frequently employed in England is that known as the Britannia joint, and is represented in Fig. 6. The ends of each of the pieces of wire to be joined are first carefully scraped and cleaned, so as to remove all oxide. About half an inch at the end of each is then turned up at right angles, and the two pieces being laid side by side for two or three inches, are carefully and tightly bound round with galvanised binding wire. The bent ends should then be cut short, as otherwise, when

blown about by the wind, they are apt to hook the next wire, and thus make a false contact.

In order to make the joint more secure, the whole is very frequently made tight by soldering, and many engineers consider this of the utmost importance, but in towns it is almost given up, and little or no practical inconvenience is found to accrue. It adds, however, to the strength to employ solder, since the wires sometimes become injured by the twisting, and then, after a time, yield and break.

The other joint commonly employed is known as the twist joint, and in France it is almost universally adopted. To make this it is necessary to have the ends of the wires quite soft and pliable, as otherwise they will break off short, and cause much inconvenience and delay. When carefully cleaned, they are laid side by side for about five or six inches; the end of each is then carefully and tightly twisted round the other, a space of about an inch being left in the middle, to avoid turning the wire too sharply, and thus injuring it. In order to make this joint, it is necessary to have a clip of some kind to hold the wires firm while they are being twisted. The French usually employ two small screw-clamps fitted with handles, and with the aid of these the joint is easily made. In this country an ingenious arrangement, consisting of two steel bars, jointed in the middle, is used. One or other of these two joints is almost universally adopted.

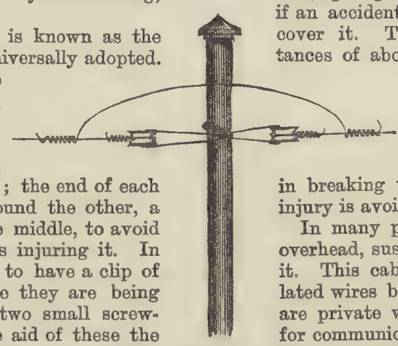


Fig. 5.

The wire employed is carefully tested for strength, and also for ductility. Short pieces of it are gripped between two vices six inches apart, which are then twisted in opposite directions, and the wire should stand from fifteen to thirty twists, according to its size, before it breaks; it is also tested by the application of weights so as to find its breaking strain. As few welds as possible should be allowed, and these should be carefully tested, as it is usually at these places that the wire breaks. It is a very good plan, when stretching the wires, to draw them as tight as practicable by means of a block, and then let them be pulled sideways with considerable force. In this way they will be straightened, and the weak places very probably detected. They may then be pulled tighter and fastened to the insulators.

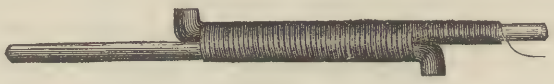


Fig. 6.

Fig. 7.

When a number of wires are placed on the same posts, care is required to ensure a sufficient distance between them, as otherwise, when they become a little slack, and are swayed by the wind, they will touch. The lateral interval, when the posts are at the usual distance of about sixty yards, should be at least twelve or thirteen inches, and the vertical distance ten inches. If the posts are further apart, greater distances should be given.

When the wire is affixed to a terminal insulator it should not be twisted, as in that case it is very likely to break. The end should be slightly turned up and then passed round the insulator, and securely bound after the plan shown in section at Fig. 8.

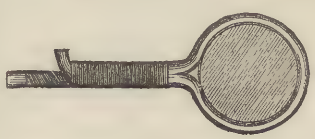


Fig. 8.

Telegraph posts should always be provided with a pointed wire projecting above the top, and connected with the ground, so as to serve as a lightning conductor. From their elevation they attract the lightning, and were it not for these conductors, it would pass along the lines and often do serious damage to the instruments or fittings.

In most cases the wires are suspended in the air in the way we have been explaining. Occasionally, however, they are placed beneath the surface of the ground or the sea; and then, of course, they must be insulated along their entire length. Sometimes, to avoid the inconvenience of fixing wires on the roofs of houses, or the danger of their crossing public thoroughfares, they are laid under the paving stones at the side of a street. The usual plan is to lay a metal pipe in a narrow trench, and to place the wires inside this pipe so as to protect them from accidental injury. Copper wire is usually employed, and as it is a much better conductor than iron, and has no strain to support, it may be used of a much less diameter.

The simplest plan of insulating it, and that almost universally adopted, is to apply a coating of gutta-percha to it. This is carefully laid on when quite soft and warm, and on cooling forms a firm protection, and being a good insulator prevents the escape of the fluid. Sometimes a second or third coating of gutta-percha is applied outside the first, so that if an accidental flaw exists in the one, the other may cover it. The wires are usually brought up at distances of about a mile, into iron pillars arranged for the purpose, so that in the event of any interruption of the communication, the wires can be tested, and the exact position of the fault ascertained. In this way much unnecessary trouble in breaking up the streets to discover the place of the injury is avoided.

In many parts of London, a small cable may be seen overhead, suspended from two wires placed a little above it. This cable contains a large number of separate insulated wires bound together in one bundle. Most of these are private wires employed by different business houses, for communicating with branch offices, or manufactories. The instruments commonly used in these cases will be described in a future paper. The wires being coated with gutta-percha are completely insulated from one another, and single ones are brought out of the bundle at any required place.

In a few instances subterranean lines are laid for considerable distances, but in these cases some additional protection is usually given, as it is found that the gutta-percha alone, if exposed to the air, or to moist ground, perishes in a few years and becomes almost useless. On this account all external connections from offices which are made with this wire (and most are made with it) ought to be covered with tape, and to receive a good coating of Stockholm tar once or twice every year. When this is done they will last almost indefinitely. In very exposed positions, it is better to protect them still further by enclosing them in a pipe, or putting a wood-casing round them.

As this wire is so much used, especially in important positions, it will be well here to explain the way in which joints may be made in it, according to the instructions given by the Gutta Percha Company, who are the chief manufacturers of the wire.

A few narrow strips of the very thin sheet gutta-percha should be in readiness, and also a little warm gutta-percha about one-eighth of an inch thick. One or two tools for heating, and a spirit-lamp are also required. Having softened the wire by warmth, the covering may very easily be stripped off with a knife for just as far as is requisite to make the joint. The ends should be well cleaned, joined, and soldered in the usual way with the twist joint. Sometimes, as an additional precaution, the joint is bound with thin wire before soldering. The gutta-percha on the wire beyond the joint should be softened and tapered down to the wire.

Now take a narrow strip of the thin sheet, and fixing it to the warm tapered part, twist it spirally along all the joint, and fasten at the other side. Having done this, gently warm the surface; then lay on in the same way as before a second strip, wrapping it round in the reverse direction, and warm again. Sometimes a third strip is added as an additional safeguard, and in important places it is well to do so. Outside this lay on a layer of the thicker gutta-percha, taking care to make a good contact with that covering the wire beyond the joint, and smooth and finish off the whole with a warm tool. With care and cleanliness, a joint thus made is as secure as the rest of the wire. Moisture or dirt, however, if allowed to enter during the process, will impair the joint very much.

APPLIED MECHANICS.—III.

BY ROBERT STAWELL BALL, LL.D.,
Astronomer-Royal for Ireland.

EXPERIMENTS ON THE THREE-SHEAVE PULLEY-BLOCK — DIFFERENTIAL PULLEY — EPICYCLOIDAL PULLEY — CONCLUDING REMARKS.

THE three-sheave pulley-block has been described in "Mechanics."—XI. (POPULAR EDUCATOR, Vol. II., page 61, Fig. 74). Our duty is to describe the mode of experimenting with it, to record the results, and to explain their significance.

One experiment will be fully explained, as by this means the process will be better understood. The sheaves were about 2″·5 in diameter, and the rope used was what is called technically "imperial patent sash line." A weight of 228 lb., not including the weight of the block itself, was attached to the hook of the lower block. According to the theory of virtual velocities, a power one-seventh of this should be sufficient to raise this load, but a power of 38 lb. was found not sufficient, though if the load were raised a little, 38 lb., or indeed less, would prevent it from overhauling. It was found that a power of 56 lb. was necessary in order to raise the weight, so that the power is seen to be about one-fourth of the load, instead of one-sixth. A series of experiments with different loads was tried, and the result is given in the table below.

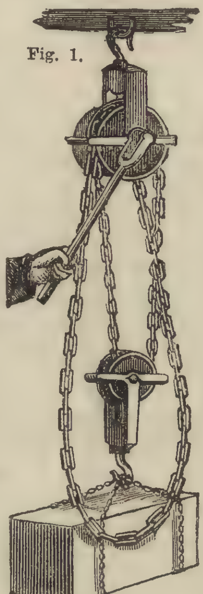


Fig. 1.

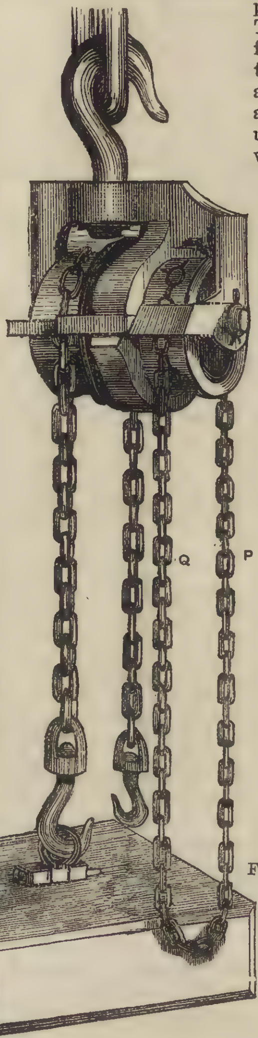


Fig. 3.

The first column shows the number of each experiment, (there were eight in all); the second column gives the load, which was in each case suspended from the lower pulley-block; and the third column gives the corresponding value of the power. From columns 2 and 3 the formula—

$$P = 2{\cdot}36 + 0{\cdot}238\ R$$

has been calculated to be that which represents the relation between the power P and the load R with the greatest fidelity. The calculated values are shown in the fourth column, and they are compared with the observed values in the fifth column, which shows the difference between the two. Thus, for example, in Experiment 7 a load of 395 lb. was found to be raised by a power of 97·0 lb.; but had we used the formula we should have found—

$$2{\cdot}36 + 0{\cdot}238 \times 97 = 96{\cdot}4.$$

THREE-SHEAVE PULLEY-BLOCK, SHEAVES 2″·5 ON WROUGHT-IRON AXLES. FORMULA $P = 2{\cdot}36 + 0{\cdot}238\ R$.

Number of Experiment.	R Load in lb.	Observed Power in lb.	R Calculated Power in lb.	Difference of Observed and Calculated Values.
1	57	15·5	15·9	+ 0·4
2	114	29·5	29·5	+ 0·0
3	171	43·5	43·1	− 0·4
4	228	56·0	56·6	+ 0·6
5	281	70·0	69·2	− 0·8
6	338	83·0	82·8	− 0·2
7	395	97·0	96·4	− 0·6
8	452	109·0	109·9	+ 0·9

On examining the table it will be seen that the difference, 0·6, between the calculated power and the observed power is shown in the fifth column. It will be noticed that the differences between the calculated and the observed values are always very small. This shows that the formula represents the experiments with accuracy.

THE DIFFERENTIAL PULLEY-BLOCK.

A pulley-block which has been introduced within the last few years, and which has been found of the utmost practical utility, has been called the Differential Pulley-block. It is a convenient adaptation of a mechanical principle * which is of considerable antiquity, but has never been embodied in a practicable machine until this happy invention. The principle of the machine will be understood from Fig. 2, which shows in a diagrammatic form the action of the pulley, while its general appearance is given in Fig. 1. It consists of a fixed and a movable block, and an endless chain. The upper block, A (Fig. 2), is composed of two sheaves, which are, however, in one piece, and turn together. One of these sheaves is a little greater in diameter than the other. The lower sheave, B, only differs from the ordinary movable pulley in having small ridges in its groove, in order to receive the links of the chain properly. An endless chain connects the two blocks; the course of this chain is indicated in the diagram by the arrows. From P, where the power is applied by the hand, the chain passes over the larger sheave, then down under the movable pulley, then up again around the smaller sheave, and back again to P.

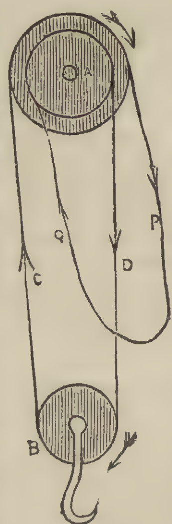


Fig. 2.

The action of the machine will now be easily seen. The upper sheave winds up the chain on the side marked C, and at the same time lowers it on the side marked D, as indicated by the arrow; but since the groove by which the chain is raised is larger than that by which it is lowered, it follows that the chain must be wound in a little faster than it is lowered out; hence the pulley, B, must be raised gradually. The origin of the name is then evident: the raising of the load is due to the difference of these actions. By having the chain endless, a much smaller length of chain will suffice than would otherwise be necessary.

The velocity ratio of the differential pulley is most easily ascertained by measurement. Thus, in a pulley of this class which is adapted for raising weights up to a quarter of a ton, the velocity ratio is 16. This was found by observing that sixteen feet of chain must be pulled out of the upper block in order to raise the hook one foot. But the mechanical efficiency of this machine is by no means sixteenfold. Attaching 5 cwt. to the hook, it is found that 86 pounds must be attached to the chain in order to raise it. The power is most conveniently attached to the chain by means of little hooks, which pass through the links, and can receive the rings attached to the weights. Hence from this experiment we see that the mechanical efficiency is 6·6, or roughly, six or seven-fold. Thus, in the use of this machine, though the power of a man is enabled to lift a weight six times greater than would be pos-

* "Mechanics."—IX., Fig. 65 (POPULAR EDUCATOR, Vol. I., p. 346).

sible without this assistance, yet more than half of the energy or work which he puts into it is consumed by friction. This apparent loss of energy is not only useless, but, unfortunately, as energy is never really lost, what is not usefully employed expends itself gradually in abrading the parts of the pulley, producing what is known as wear and tear. To resist this as far as possible, the working parts of the differential pulley are specially hardened.

It often excites surprise in one who sees for the first time a differential pulley in action, that when the weight has been raised it will remain suspended without the chain being held or fastened. This property of not overhauling is one of the most useful features of the pulley. It is not only very convenient, but is a source of safety, as accidents often occur when heavy weights are raised by machines which do not possess this property. In fact, in the use of the differential pulley, when the weight is to be lowered the chain Q must be pulled, just as P must be pulled when it is being raised; by holding one of these chains in each hand, the position of the weight can be adjusted with the greatest nicety. This adds very much to the general utility of the differential pulley, and renders it a mechanical aid of great value.

That the differential pulley does not overhaul, arises solely from the fact that more than half the power which is applied is lost by friction, and therefore when friction acts to prevent motion it is more than sufficient for the purpose. This property applies to all the mechanical powers where the mechanical efficiency is less than half the velocity ratio; as, for example, in the screw, but not in the three-sheave pulley-block.

The handle which is attached to the upper block of Fig. 1 shows a modification of the differential pulley, which is sometimes useful; by turning this lever the block is turned round, and therefore the load is raised; by having a long lever the power can be greatly increased. By this means a man is enabled to lift a ton or even more without using any very great exertion, but the rate at which the weight is raised is, of course, very slow.

EXPERIMENTS UPON THE EPICYCLOIDAL PULLEY.

In Fig. 3 we have represented another kind of pulley, which is often called the epicycloidal pulley-block. In this there are two chains—one stout chain with a hook at each end, on which the load is carried; the other a smaller chain, which passes over a sheave in the upper block, and by means of which the power is applied. Holding one part, P, in one hand, and the other part, Q, in the other hand, the weight can be raised and lowered with the greatest facility. The mechanical power of this pulley is about fivefold, and as its velocity ratio is 12, it follows from the principle already laid down that the weight cannot overhaul.

There being two distinct hooks on the load-chain, one of these hooks is always low down and convenient for raising, when the other has carried up its load. This is a practical convenience which, as the student may have noticed, is not met with in the differential pulley.

CONCLUDING REMARKS.

The values of the velocity ratios and mechanical efficiencies which have been given in this lesson for differential pulleys apply only, of course, to the actual specimens which have been examined. Various sizes of differential pulley-blocks are made, but the one here referred to is that size adapted for lifting a quarter of a ton; the more general principles apply to all sizes, but it was thought better to describe fully one form. The same remark may be made about the epicycloidal pulley-blocks.

Various other blocks differing more or less from those mentioned are met with. The way to study them is to perform the two processes here described. First, measure the distance through which the power must be moved when the load is raised one foot; then attaching a given load to the load-hook, see what power will raise it. The first operation gives the velocity ratio; the second, the mechanical efficiency. A comparison of these numbers, which would be equal in a perfectly frictionless machine, shows how much of the power is lost by friction. And we cannot repeat too often, that when the mechanical efficiency is reduced by friction to less than half the velocity ratio, the machine does not overhaul.

CHEMISTRY APPLIED TO THE ARTS.—III.

BY GEORGE GLADSTONE, F.C.S.

DYEING (*continued*).

In the practical operation of dyeing the first thing that has to be considered is the material to be dyed. The same processes cannot be applied to cotton, flax, wool, silk, etc., indiscriminately; in fact, it may be taken almost as a general rule that one which will suit a vegetable fibre will not suit those derived from the animal kingdom. It is not, however, sufficient merely to divide the articles to be dyed into these two classes, for cotton and flax will not dye equally well by the same process, nor will a given amount of dye-stuff produce the same effect upon wool after it is spun or woven as before—one quality, too, of either wool or cotton will take up colours much more readily than another. Nowadays there is a great disposition to use mixed goods as articles both of dress and furniture, in which cotton and silk, or cotton and wool, or a mixture of the latter with goats'-hair, are woven together. All such, if they are to be subsequently dyed, demand much consideration as to the means to be adopted.

The animal substances are, in nearly all cases, the most susceptible to the dyer's art, more brilliant colours being produced upon silk than on any other material. Woollen goods also dye very well; the scarlet of our soldiers' coats, which is produced by cochineal mordanted with oxide of tin, being a colour the equal of which cannot be attained on any vegetable tissue. It is, therefore, a matter of no little difficulty to dye a mixed fabric of an even colour.

By the aid of chemical solvents, if other means fail, the dyer can at once detect any mixture in the materials of which the cloth to be dyed is made. For instance, bichloride of tin, when heated moderately, will turn vegetable fibres black, while animal substances will remain unaltered. If a mixed fabric of cotton and wool be boiled in caustic soda, the wool will be dissolved and the cotton will remain untouched. Again, cotton is whitened by chlorine, but silk and wool are turned yellow. Having determined this point, the next step is to prepare the article for dyeing. Of whatever material the goods may be made, it is necessary to free them from grease, iron-mould, or any other accidental impurity; and if they are to receive any light or delicate tints, they must be properly bleached. If the goods are fresh from the manufactory, they are sure to contain either grease or some dressing; and if they are old, there will probably be some accidental stains, which will reappear more or less after dyeing, if they are not first eradicated.

The material being thus prepared, the subsequent processes will depend much upon the article of which it may be made. Confining our attention at present to simple fabrics, we must take them separately.

Silk.—To produce a good colour, silks should first be immersed for some hours in a strong solution of alum, which must be dissolved in cold water, for if applied hot it is injurious to the lustre of the silk. After the aluming, they should be thoroughly washed in pure water. A good permanent red may then be produced by a mixture of cochineal with bitartrate of potash and spirits of tin. For a yellow, weld is very commonly employed, the silk being put into a hot solution in which some soda is dissolved, the quantity of the latter depending upon the shade desired, an increase of the soda rendering the colour more intense. For blues, recourse is generally had to indigo, with the addition of a little potash and madder, the vat being kept moderately warm during the process. There is, however, considerable difficulty in producing an even colour with this dye, and the silk should be dried rapidly when taken out of the vat. To obtain an intense black, it is necessary to deprive the silk, as much as possible, of the gummy substance naturally belonging to it, which is done by boiling it in a strong solution of soap—a desirable thing, by the way, in every case, as all the colours take better the more thoroughly the gum is removed. This being done, it is steeped for a day or a day and a half in a very strong decoction of galls, or one of the other substances mentioned in the previous article as having the same chemical property, after which it is immersed in a solution of sulphate of iron. Greens are usually produced by dyeing the silk yellow in the first instance, and then blue. Violets and purples may be obtained by dyeing first with cochineal (no tin being added to it in this case) and subsequently with indigo, the relative

strengths of the two dyes being adjusted according to the tint desired. For all these combinations, however, the aniline dyes are now superseding the others. Magenta and mauve have a great affinity for silk, and the operation is consequently very simple: a solution of the dye is made in cold water, and the silk worked in it until it has acquired the requisite depth of colour.

In all cases the silk, after being taken out of the dye, must be washed in cold water before being hung up to dry.

Wool.—Care must be taken to rid the stuff of the grease it always contains by scouring it well in soap and water or a strong solution of soda for several hours. It is then ready to receive the dye, which is always to be applied hot, the wool being afterwards washed in cold water. It can be dyed blue by indigo in the manner described in the previous article for dyeing cotton, except that the vat must be kept at an elevated temperature. For woollens, however, the vat is more generally prepared in another way, and goes by the name of the "pastel vat." The difference consists in substituting for the sulphate of iron and the large quantity of lime, other ingredients for deoxidising the indigo, one of them acting the part of a dye at the same time. Pastel or woad was, indeed, used almost exclusively 200 years ago for dyeing blue, but has since been nearly superseded by indigo, on account of the latter giving a richer colour. To prepare a vat, about 400 lb. of woad, 20 lb. of madder, 10 lb. of bran, and 8 lb. of lime have to be boiled up together. In the course of twenty-four hours it will be in a state of fermentation, and the bath will have acquired a yellowish tint. It is then ready to receive the indigo—say about 20 lb., with a further addition of about half that weight of lime—and in about six hours more the indigo will be converted into the white soluble state previously described. The wool is then dipped in the vat for about an hour, after which it is hung up in the air to dry, during which process it turns blue; the dipping being repeated several times if very deep shades are required. This vat, when once prepared, will last for months, but the supply of indigo must be renewed from time to time as its strength becomes exhausted.

The substances employed for dyeing red in all cases require a mordant to fix them. If madder be used, the cloth should be first steeped in a solution of alum and bitartrate of potash. To produce a brilliant scarlet, a little cochineal should be boiled up with bitartrate of potash and spirits of tin; and after the wool has been dipped in this mixture, washed, and dried, it should be immersed in a second bath containing a strong solution of cochineal. Lac is used for the same purpose, and with the same mordants. To obtain a good black, the wool is first dyed blue, then boiled in a solution of galls or any of the other articles previously named which possess the same properties, and finally in a bath of sulphate of iron. For a green it is generally found best to dye the stuff blue first, and afterwards yellow. For violets and purples the blue should form the foundation, though some shades of these compound colours may be made in the bath by a mixture of the various ingredients, by which a saving is effected in the number of operations. Mauve and the other aniline dyes also act very readily upon wool by merely working it in a lukewarm aqueous solution.

Vegetable fibres are not so readily dyed as those already considered, nor can colours of equal brilliancy be produced upon them. After the fabrics made of them have been properly cleansed they are subjected to the operations of aluming and galling. The materials used for these purposes are sufficiently indicated by the respective terms.

Flax.—After being thus prepared, it may be dyed red with madder by a process similar to that used in dyeing cotton Turkey red, which will be considered presently. This is almost the only shade of red which can be produced as a fast colour on vegetable tissues. Quercitron furnishes a beautiful and permanent yellow. For blues, indigo is almost invariably employed. A thorough black is not readily obtained, but the most approved plan is first to dye the linen with a deep blue, then steep it in a strong decoction of galls, and finally in a bath containing one of the salts of iron along with acetic acid.

Cotton is generally dyed in the same way as flax. The mode of using indigo has already been described in detail in the previous article. The Turkey red process is certainly the most complicated of all, but it demands special notice, as it is very extensively carried on, particularly in Glasgow and Manchester, and produces one of the most durable colours known. The little minutiæ must inevitably be omitted for the sake of brevity, and only the most characteristic operations described, though very great exactitude in all the details is necessary in order to produce a thoroughly satisfactory result. The cloth, having been carefully freed from the weavers' dressing, is steeped three successive times (being dried on the grass between each) in a bath containing the following ingredients to 15 gallons of cold water:—1 gallon of olive oil, 1½ of sheeps' or cows' dung, 4 gallons of a solution of carbonate of soda, and 1 gallon of a solution of pearlash. The steeping in this liquor should last for a fortnight at least. The cloth is then passed through a warm and weak solution of pearlash, steeped again three times as before in a bath containing 1 gallon of olive oil and 3 of soda lye to 18 of water; and then passed again through a wash of soda and pearlash. These may be considered the preparatory processes, the chief peculiarity of which consists in the use of oil and dung, which together act as a mordant upon the outer surface of the cotton fibre, and prepare it to take up the dye that is subsequently to be applied. The alkali through which the fabric is passed saponifies and carries off any excess of oil remaining over from the preceding operations, the rest being apparently decomposed by the action of the other ingredients with which it is mixed. The cloth is next galled with a decoction either of gall-nuts or sumach, and then alumed, without which the dye would not be permanent. The colouring matter used is madder, to which some bullocks' blood is added, the quantities varying according to the intensity of the colours required. The fabric is put into the dye when cold, which is then raised to the boiling-point, and kept at that temperature for a couple of hours. It is finally boiled in an alkaline solution in which a little protochloride of tin is dissolved, and then spread out to dry. The great peculiarity of this process is, that while the usual object to be attained in dyeing is to fill the internal cavity of the transparent fibre with a colouring matter which shall be insoluble, the Turkey red dye is principally deposited on the outer surface, and has entered into actual combination with the fibre itself—a circumstance to which both the permanence and the brilliance of this dye is attributed. Mauve, or any of the aniline colours, will dye cotton; unlike silk or wool, however, the fabric must be mordanted in order to produce a fast dye. It is best to soak it first in a decoction of sumach, galls, or other article rich in tannin, and then pass it through a weak solution of stannate of sodium. Being thus prepared, the cotton will absorb the dye most readily.

Hitherto attention has been directed to the dyeing of fabrics made exclusively of one material. The mixed goods have also to be dyed, and that either of one or more colours; for instance, a damask may be dyed of one uniform colour, or the cotton may be of one and the wool of another. In either operation the affinity of the materials for different colouring matters has to be taken into consideration, as well as the manner of applying them; picric and rosolic acids, for instance, cannot be used for dyeing cottons, nor are the compound cyanides of potassium and iron applicable to woollens. With mixtures of cotton and wool it is nearly always necessary to dye the latter first, as it is more tenacious of the colours imparted to it; but if the cotton is to be blue the order of proceeding is reversed, the indigo dye being so fast as to be unaffected by the subsequent operations upon the wool. It is not so easy to produce different colours upon a mixture of silk and wool, because they are both animal substances, and are each more or less acted upon by the same ingredients; the silk, being more retentive, is, however, generally dyed first. With a mixed fabric composed of silk and cotton the same order is followed.

There are two ways of dyeing mixed fabrics of one uniform colour—either separately or at one process. Let us suppose that a mixture of cotton and wool has to be dyed black. The latter can be dyed first with camwood and sulphate of iron in the manner already described, and then the cotton in a solution of sumach followed by sulphate of iron. They may, however, be dyed simultaneously (and even if the fabric should also contain silk the process will apply) by steeping the article in a decoction of sumach, and then in a solution containing equal parts of bitartrate of potash, sulphate of iron, and sulphate of copper; after this with logwood, and again with the sulphate of iron. Other colours besides black may be produced upon mixed goods by a single process; the adjustment of the in-

gredients needs, however, considerable nicety, in order to adapt them to the varied powers of the materials in taking up the different dyes.

Throughout the paper it has always been taken for granted that the materials are the best of their respective sorts. Many of them unavoidably vary considerably in quality, while others, again, are in such a condition as to be easily adulterated. It is very important, therefore, that the operator should be thoroughly assured both as to the purity and quality of the ingredients, or he may be grievously disappointed in the result.

PROJECTION.—VII.

CYLINDERS AND CONES.

PLAN AND PROJECTION OF A SPEED-PULLEY (Fig. 89).

THIS is a further application of the lessons on the projection of cylinders, wheels being, as it were, sections cut from cylinders. The subject is composed of three pairs of parallel circles. Having drawn the plan, describe on A B a semicircle, and divide it into any number of equal parts in *c*, *d*, *e*, *f*, *g*. From each of these points draw lines meeting A B at right angles in $c' \; d' \; e' \; f' \; g'$. These lines will cut C D in c'', d'', e'', f'', g''. Draw a line, X X, at a height above I L equal to the radius of the circle—viz., e' e. From A B, and all the points between them, draw perpendiculars passing through X X, and on these perpendiculars set off on each side of X X distances corresponding to the distance between the point similarly lettered in the semicircle and the line A B, as $e \; e'$, $d \; d'$, etc., and this will give the points A$'$, B$'$, C$'$, D$'$, E$'$, F$'$, G$'$, through which the ellipse is to be drawn. From each of the points last mentioned, draw horizontal lines, and intersect them by perpendiculars from the points C, d'', e'', etc., in the plan, and the intersections of the lines correspondingly lettered will give the points E$''$, D$''$, A$''$, etc. The other two wheels are to be projected in precisely the same manner from semicircles equal to half their surface. The lettering of these is omitted in order to avoid confusion in the diagram; but the student, who is expected to work on a much larger scale, is advised carefully to letter every point.

CONES AND THEIR PROJECTION.

A cone is a solid, the base of which is a circle, and the body of which tapers to a point called the *apex*.

The straight line drawn from the centre of the base to the apex of the cone is called the *axis*.

When the axis of the cone is perpendicular to the base, the cone is called a "*right*" cone; but when otherwise, it is called an "oblique" cone.

The curved surface of a cone is equal to the sector* of a circle, the radius of which is equal to a straight line drawn from any point in the circumference of the base to the apex, and the arc-line of the sector is equal to the circumference of the base of the cone.

Fig. 90 is the plan and elevation of a cone when standing on its base, its axis being perpendicular to the horizontal and parallel to the vertical plane. The apex is thus over the centre of the plan, and the solid is therefore called a *right* cone.

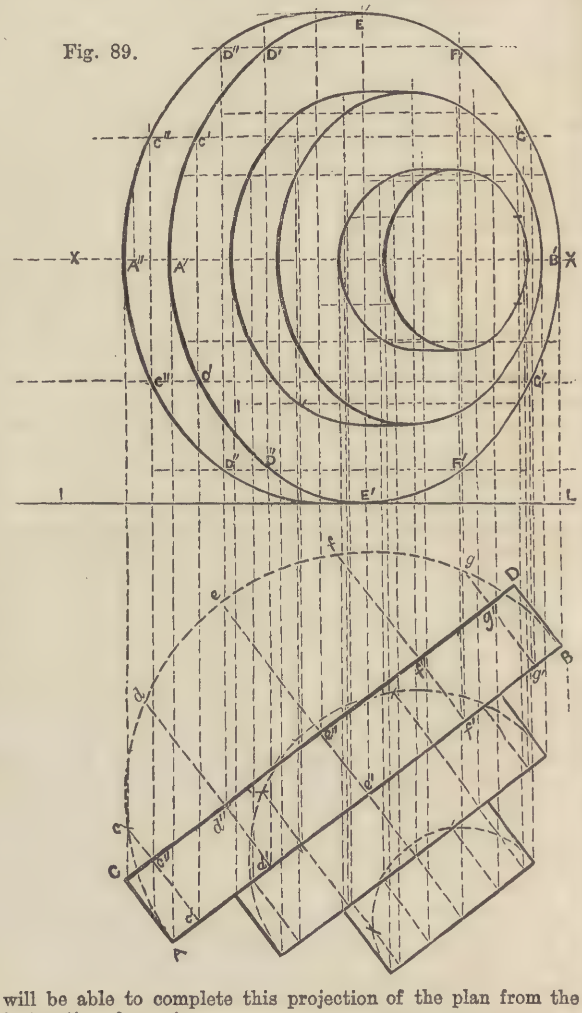
Fig. 91.—To draw the plan of this cone when lying on the horizontal plane with its axis parallel to the vertical plane, draw the elevation lying on I L. To do this, at any point in I L construct an angle similar to A B C in the elevation; make the sides of the angle equal to those of the elevation, and join A$'$ C$'$. Bisect the angle, and produce the bisecting line to D. This will be the axis. Now begin the plan by drawing C B parallel to I L. From D in the elevation, with radius D A, describe a semicircle, and divide it into any number of equal parts in *e*, *f*, *g*, *h*. From each of these points draw lines meeting A C at right angles, and from these points of meeting drop perpendiculars passing through C B on the points *e*, *f*, D, *g*, *h*. Set off from these points on their respective perpendiculars, and on each side of C B, the lengths of the lines between A C and the semicircle, and by this means the points through which the ellipse is to be drawn will be obtained. Join the point B to each end of the ellipse, which will thus complete the plan. The students should now, as an exercise, turn the plan so that its axis is at a given angle to I L, and then make a projection from it and the present elevation.

* A *sector* is a part of a circle contained between two radii and a portion of the circumference.

Fig. 92 shows the elevation and plan of the cone when resting on the extremity of one diameter of the base, the plane of which is at 30° to the horizontal plane.

It will be evident that whether the cone lies on the paper, or stands on one extremity of a diameter of its base, so long as the axis remains parallel to the vertical plane, the elevation will be the same in *form*—changed only in position—and therefore the line which is the elevation of the base has been placed at the required angle. Construct on it an isosceles triangle of the given altitude, which will form the elevation of the cone. It must here be remarked that this figure and the next have been left unlettered, so that the student may become gradually accustomed to follow the points through their various change of position; and, with Fig. 91 to guide him, it is thought that he

Fig. 89.



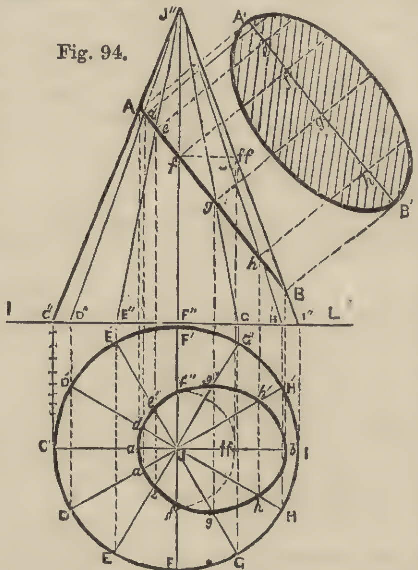
will be able to complete this projection of the plan from the instructions here given.

It will be remembered that although the base of the cone is rendered by a straight line in the elevation, that line is the *edge elevation* of a *circle*; therefore, from the middle point in the line describe a semicircle, which will represent one-half of the base, turned up so as to be parallel instead of at right angles to the vertical plane. Now divide this semicircle into any number of equal parts, and from each of these draw lines at right angles to the diameter. Next draw a line in the horizontal (or lower plane) parallel to I L, and a portion of this line will become the axis of the cone. From each of the points in the base of the cone draw perpendiculars passing through this horizontal, and make them the same length on each side as the lines drawn from the points in the semicircle to the diameter. Through these points trace by hand the ellipse, which represents the plan of the base, being the view from a point imme-

diately over it. Drop a perpendicular from the apex of the elevation to cut the horizontal, and this intersection will be the plan of the apex. Join this by straight lines to the widest parts of the ellipse, and this will complete the projection.

Fig. 93 is the projection of the cone when the base is at 30° to the horizontal, and its axis at 45° to the vertical plane. It has been shown in several previous figures that an object may be rotated without the height of any part of it being altered; and thus, as in the projection now required, the base of the cone is to be at an angle to the horizontal plane similar to that of the last figure, the plan will be the same in shape, but altered in position; therefore, repeat plan of Fig. 92, placing it so that the axis is at 45° to I L; then draw perpendiculars from all the points in the ellipse, and cut them by horizontals from the points in the elevation. Draw the projection of the base through the intersections. Draw a perpendicular from the point which is the plan of the apex, and a horizontal from the apex in the elevation. The intersection of these will give the apex of the projection. Join this point to the ellipse representing the base, which will complete the figure.

Fig. 94.



SECTIONS OF CONES.

If a cone be cut across, so that the plane of section may pass through the axis at an angle, and cut the slanting surface of the cone on the opposite sides, the section is called an *ellipse*.*

TO DRAW AN ELLIPSE WHICH SHALL BE THE TRUE SECTION OF A CONE ON A GIVEN LINE.

Let Fig. 94 be the plan and elevation of the cone, and A B the line of section. Divide the circumference of the plan into any number of equal parts in C, D, E, F, G, H, I, and D′, E′, F′, G′, H′, I′, and draw radii. Project these points on to the base of the cone, and from C″, D″, etc., draw lines to the apex J″. The diagram up to this point represents a cone, up the slanting surface of which straight lines have been drawn, which on looking down on the apex would appear as radii of the circle forming the plan.

The line E″ J″ in the elevation is therefore the radius E J in the plan, and thus the plan of any point marked on E″ J″ must fall somewhere on the radius E J. Now the section-line A B cuts through all the lines drawn to the apex of the cone in the points *d*, *e*, *f*, *g*, *h*, and it will be remembered that, although in the elevation the section is represented by a single line, A B, it will assume a different form in the plan. From points A and B draw perpendiculars cutting the diameter C I in *a* and *b*, and from *d*, *e*, *g*, *h* in the elevation draw perpendiculars cutting the radii of the plan which bear the same letters. Draw the curve, which will unite *e′d′ade*, and also the curve uniting *g′h′b hg*. It will at once be seen that these two curves form the ends of an ellipse which is to be the *plan* of the section, but that a point is wanted on F and F′ in order to complete the figure. But we cannot draw a *perpendicular* from the point *f* in the elevation, to cut the radius F in the plan, as we have done in the other lines, *because the radii* F F′ *are but portions of the same perpendicular on which the point f is situated*, and therefore no intersection can be obtained.

Now let us remember that the line F″ J″, though appearing perpendicular to I L when looked at in its present position, would, if looked at from K, in the direction of the arrow, be seen to be as much a portion of the slanting surface of the cone as I″ J″, and therefore the line F″ J″ would be seen to make the same angle with the horizontal plane as I″ J″. If therefore we rotate the cone on its axis, the point *f* will move to *f f*, and a perpendicular drawn from *f f* will give us *f f* in the plan. If now we turn the cone to its original position (which will be represented by drawing a quadrant from the centre of the plan with radius J *f f*), the quadrant will cut the radius F in *f′* and F′ in *f″*. Join *e* and *g* and *e′* and *g′* by curves passing through *f* and *f′*, which will complete the plan of the section. This is not the *true section*, but the view when looking straight down upon it, and as it is slanting, its length from *a* to *b* will seem shorter than it really is. It will be evident that the true length of the section is the line A B. From these points, and also from *d*, *e*, *f*, *g*, *h*, draw lines at right angles to the section-line, and A′ B′ parallel to it. On each side of the points *d*, *e*, *f*, *g*, *h*, in the line A′ B′, set off the distances which the points similarly lettered are from C I in the plan, and these will give the points through which the true section may be drawn.

Fig. 90. Fig. 91.

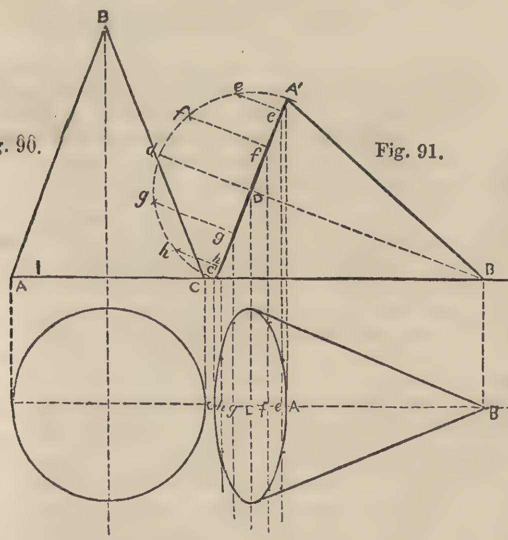
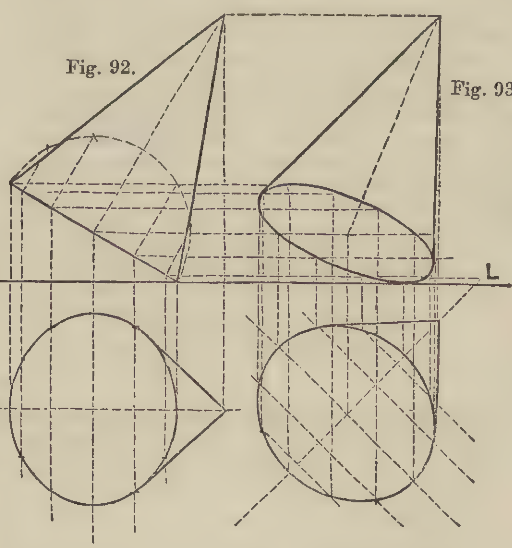


Fig. 92. Fig. 93.



* An ellipse differs from an oval by being the same shape at both ends; but in an oval, the one end is more pointed than the other.

TECHNICAL EDUCATION ON THE CONTINENT.—V.

BY ELLIS A. DAVIDSON.

THE POLYTECHNIC SCHOOL IN HANOVER—COURSE OF STUDY (*continued*).

12. *Architecture.* (First course, lectures, three hours per week, and six hours drawing.)

The course is divided into three sections.

(*a.*) The setting out of plans; stone, wood, and iron constructions.

(*b.*) Ancient architecture, and architectural form, one hour lecture, and four hours drawing, weekly; æsthetics; illustration of the forms of Greek architecture; its constructive and æsthetic principles; the general principles of Greek ornamentation.

(*c.*) The construction of simple buildings (three hours weekly).

13. *Architecture.* (Second course, two hours lectures, and four hours drawing, weekly.)

(*a.*) Building construction:—The construction of staircases; arrangements for heating; the work of the carpenter; plasterers and decorators.

(*b.*) Architectural form:—Perspective (two hours lecture and four hours practice weekly):—Study of form as developed in the Roman, Early Christian, and Romanesque architecture; their æsthetic and constructive principles, and their history; the principles of Gothic architecture.

(*c.*) Rural architecture (one hour lecture and two hours drawing per week):—The construction and arrangement of various classes of rustic dwellings and agricultural buildings; the arrangements of farms, etc.

(*d.*) Ornament (one lecture weekly, and drawing three hours):—Special characteristics of Antique ornament; Early Christian and Romanesque styles; drawing from models and designs.

14. *Architecture.* (Third course, four hours weekly.)

(*a.*) Designing of circular buildings.

(*b.*) (Two hours weekly.) The planning and arrangement of public buildings and private dwellings of the highest class; dwellings for middle and working classes; toll-houses; station-masters' and porters' houses, etc.; factories; railway-sheds; post-offices; inns; exchanges; warehouses; shops; markets; granaries; slaughterhouses; baths and laundries; hospitals; prisons; asylums; dispensaries; school-houses; blind, deaf and dumb institutes; workhouses; gymnasia; barracks; exercise and riding-houses.

(*c.*) Details of building construction (one hour lecture, and three hours drawing, per week):—Designing of mouldings, columns and arches; window and door-framing, etc., with particular regard to the material employed; building stone; brick; wood; iron; glass, etc.

(*d.*) General considerations in relation to architecture, building works, and materials (two hours weekly):—General and special cost; valuation of old buildings; building works; the plans; letting of buildings; building contracts; building accounts; technical and financial specifications; measuring up; general survey; reporting; drawing up inventories; building materials—stone, mortar, wood, metal, etc. etc.

(*e.*) Ornament (one lecture weekly, two hours drawing):—The Romanesque and Gothic styles; drawings from casts and designs.

(*f.*) Architectural history (six hours weekly) —German antiquities and memorials in America; early Asiatic and Egyptian art; the architecture of the Greeks, Etruscans, and Romans; Early Christian art; the Mohammedan style; Mediæval art generally; the Renaissance; review of the works and progress in architecture in modern times.

15. *Architecture.* (Fourth course.)

(*a.*) Building construction as applied to extensive works; heating and ventilation (two hours weekly):—The various considerations involved in the construction of large buildings; heating; ventilation; circulation of water; baths, lighting, arrangements for telegraphy, etc.

(*b.*) The most important kinds of public and private buildings; civic architecture (two hours weekly):—Dwellings of the most expensive class—palaces; country houses; theatres; circuses; panoramas; concert halls; places of amusement; guildhalls; Houses of Parliament; courts of justice; watch-houses and gates; academies; libraries; museums; exhibitions; churches; dead-houses; monuments; garden arrangements; town building and fortification, etc. etc.

(*c.*) The design and decoration of buildings (two hours weekly):—Design and decoration of houses; the most important classes of public and private buildings; civic architecture; and necessary arrangements.

(*d.*) Designs for public buildings (five hours weekly):—The buildings specially treated of in this section are such as require the highest application of science and art, such as churches, public schools, assembly rooms, town halls, etc. The designs are all worked to an especially large scale, and consist of plans, elevations, sections, and interior and exterior perspective.

(*e.*) Designing for coloured decoration (one lecture and three hours designing per week):—Ancient and Middle Age wall-painting, glass-painting, and mosaic work; designing complete systems of interior and exterior decorations; with details to an enlarged scale.

(*f.*) Ornamentation and "small" architecture (one hour lecture and four hours drawing weekly):—Details of ornamental design in architecture applied in the construction and ornamentation of furniture and objects of domestic use, the purpose being to bring about a perfect system of harmony in a household, so that if the architecture of a room be classic, the carpet may not be Louis Quartorze and the furniture Gothic. This is not a question of expense, but of knowledge, and hence the instruction is of exceeding importance.

(*g.*) Mediæval architecture (two lectures and two hours drawing per week):—Church architecture; plans of churches; crypts; columns; bases, shafts, and capitals; buttresses; windows and tracery; towers; spires; porches; elevations; profiles and ornaments; brick architecture; timber constructions; carpenters' work; metal works; floor tiles; wall and window decoration.

16. *The Elements of Waterworks and Bridge-building.* (Two lectures and two hours drawing per week.)

Waterworks:—The regulation and utilisation of small and great streams; the arrangement and carrying out of works for this purpose; arrangements for utilising and controlling back waters and mill-streams; arrangements for the drainage and irrigation of land. Bridge-building:—Foundations under water; embankments; the general principles of the construction of bridges; the usual methods of building stone, wood, iron, suspension, and moving bridges.

17. *The Construction of Roads and Railways, Streets and Bridges.* (Three lectures weekly; two hours drawing.)

Introduction; the history of the means of transport employed in early times; general considerations in relation to the planning of streets and railways; the composition of the crust of the earth; the elements of planning; considerations as to geological formations of the site; working out of the plans; earthworks; measurement and translation of scales; the arrangement of payment and commission, etc.; plans for irrigation, cuttings, vaults and viaducts, canals, railways on similar, higher, and lower levels; the construction of roadways, railways, and railway bridges, etc. etc.

18. *Streets, Railways, and Bridges.* (Three lectures weekly and four hours study.)

Iron Bridges:—The principles of bridge construction; methods of working, and properties of wrought iron and steel; rivetting; bearers; girders; rails; sleepers; tramways for streets; the equilibrium of bridges; bridges of timber and iron combined; girder and tubular bridges; estimates of cost; practice in bridge construction; excursions to inspect works in progress.

The further history of means of transport; investigation of best systems; direction of the line; its breadth, curve, and level; arrangements of railway works; tunnelling, etc. etc.

19. Iron Bridges (*continued*):—Further development of history; springs and reservoirs of water, and means of filtering and conducting it over land; arrangements for damming water; weirs, watercourses, and waterworks generally; methods of irrigating and draining tracts of land; canals and sluices; rivers and streams; foundations in streams and rivers; sea-walls, harbours, and docks; methods of designing and preparing the necessary drawings and estimates for the construction of stone, wood, iron, suspension, and moving bridges.

20. *Mineralogy as applied to Building Purposes.* (Two hours weekly.)

The elements of mineralogy, with particular reference to the portions of the earth's crust used for building purposes; the elements of petrology; application of the various mineral substances.

21. *Geognosy.*

Recapitulation of the principles of mineralogy and petrology; the elements of palæontology in connection with geology. In connection with lectures, rock specimens and petrifactions are examined and described. (Natural history of animals, plants, and minerals is supposed to have been previously studied.)

22. *Elements of Physics.* (Two hours weekly.)

Condensed instruction on the leading facts and principles of Physics.

23. *Pure Physics.* (Five hours weekly.)

The progressive development of Physical theories, and Experimental Physics:—Lectures and practice.

24. *Applied Physics.* (Five hours weekly.)

Popular astronomy; mathematical and physical geography; meteorology; weighing and measuring apparatus; musical and optical instruments; lighting apparatus; the mechanical principles of heating apparatus; application of the theory of heat to fireplaces. The lectures are illustrated by experiments.

25. *Elementary Chemistry.* (Two hours weekly.)

Brief introduction to Chemistry, with especial reference to building and building materials, illustrated by experiments.

26. *Pure Chemistry.* (Five hours weekly.)

Inorganic and Organic Chemistry, illustrated by numerous experiments.

27. *Technical Chemistry.* (Five hours weekly.)

Apparatus for carrying out chemical operations on a large scale; the processes of manufacture of chemical products. The instruction given in this course is by means of lectures, experiments, excursions, and visits to laboratories and manufactories.

28. *Practical Chemistry.* (Twenty-four hours weekly.)

In this course, in addition to practical work, three hours per week are devoted to lectures on analytical chemistry; the students having previously attended the courses 25 and 26.

29. *Mechanical Technology.* (Five hours weekly.)

Working in metal and wood; spinning and weaving; manufacture of paper; and numerous other processes employed in the mechanical arts.

30. *Building Technology.* (Two hours weekly.)

Brief recapitulation of the practice of building art, with especial reference to materials used in finishing or decorating buildings, as glass, paper-hangings, iron, stone, and plaster works.

31. *Telegraphy.* (Two hours weekly.)

32. *Modelling.* (Ten hours weekly.)

Modelling, ornament, human and animal forms in clay and wax from drawings and casts; moulding and casting; finishing rough casts.

33. *Architectural Modelling.* (Ten hours weekly.)

Modelling in wood, roofs, trussed bridges, staircases, etc.; modelling in plaster, arches, vaults, etc. etc.

TECHNICAL DRAWING.—IX.

DRAWING FOR CARPENTERS (*continued*).

WOODEN BRIDGES.

FIG. 56 is the elevation of the bridge over the Weser alluded to in the last lesson. The bow, built up as described, abuts against oak blocks, toothed and bolted on to the ends of the tie-beam. From the bow, transverse bearers are suspended by means of seven iron rods, placed as in the drawing, and on these the beams supporting the roadway rest.

It is deemed necessary, in relation to the drawing of this example, to remark that the lines forming the joints (that is, the ends of each piece of timber) must be radii of the circle of which the arc is a part. In the present instance the arc is that subtending an angle of 60°; therefore, having drawn the tie-beam, and marked the points at which the under side of the bow meet it, with distance between these two points as radius, describe arcs cutting each other in a point below, which would be the apex of an equilateral triangle, and from this centre the arcs are to be described.

The disadvantages connected with the De Lorme system are, first, that the stiffness of the span must depend mainly upon the natural strength with which the fibres of the wood adhere to each other; and as this is of course limited, it is necessary to construct the curved rafters of greater width than would otherwise be required, in order to ensure them against the strain to which they may be subjected. Secondly, there is, from the circumstance above alluded to, and from the necessity of sawing the segments out of straight timber, a great waste of material, time, and labour.

These considerations naturally prevented the system becoming very general, and in 1809 an improvement thereon was proposed by a celebrated Prussian architect named Wiebeking, which was in 1817 perfected by Colonel Emys, a French military engineer, and which has since been extensively used.

By Emys' system, the arched ribs are laminated—that is, formed of "laminæ," or thin layers of timbers—not placed edgeways, as in the De Lorme plan, but laid flat on each other, the break-joint system being still preserved, and the planks being held together by iron straps with which they are surrounded.

The whole rib is then confined by its ends fitting into cast-iron shoes bolted on to the tie-beam. Thus all the fibres of the wood coincide with the curvature of the rib, and thus not only are they not liable to be torn asunder, but a great amount of elasticity is obtained. As this system has been extensively used in the construction of roofs, it will be further described in the section devoted to that subject, and the attention of the student is now directed to the elevation of one of three arched ribs of a wooden railway bridge (Fig. 57).

Here the tie-beam is formed of double timbers, resting on an additional piece at each end.

The bow is made up of seven layers of timber, united in the manner shown in Fig. 58, which is an enlarged drawing of the middle portion of the truss.

Seven perpendiculars are placed between the bow and the tie-beam, by which the latter is suspended, as by king and queen posts. The mode in which the iron bands, nuts, and screws act in such cases is described in connection with Roofs in "Lessons on Building Construction."

The trusses are further stiffened by diagonal struts between the perpendiculars. Across the tie-beams of the three ribs the sleepers are placed on which the flooring of the bridge and the rails are laid.

The piers, saddle-pieces, and tie-beams having been drawn, the arc forming the upper edge of the bow is next to be described. The cast-iron shoes necessarily follow. In the smaller view (Fig. 57) their outer edge is shown as continuous with the arc of the bow; but in working this figure to a larger scale, this should be drawn with a rather wider radius, so that the iron shoes may project to allow for the thickness of the material. As in the case of the cross-joints of the timbers in the De Lorme bow truss, the third side of the cast-iron shoes and the bands by which the laminæ are clamped together are radii of the circle of which the bow is a part, and therefore converge to the same centre. This is not, however, the case with the irons by which the uprights are suspended. These plates, which end in screws, are, of course, placed parallel to the posts; at the top a cross-plate unites the screws, on which are washers and nuts. The irons at the bottom of the perpendiculars are similar in character.

When the bow has been completed, the perpendiculars for the centres of the uprights are to be dotted in, and on each side of these half the thickness of the supports is to be drawn. The upper and lower ends of these are, of course, wider than the middle part, the two widths being joined by short oblique lines.

Now, from the points where these oblique lines join the outer to the inner width, and so form a "head," draw diagonals in the interspaces, which will form the centre-lines for the struts. It will be observed that the oblique lines, which form part of the ends of the struts, are at right angles to their sides. It is presumed that this drawing can be finished without any further instructions.

The student is required, in the first case, to draw Fig. 57 to the size of Fig. 58, and then to repeat the whole figure, making

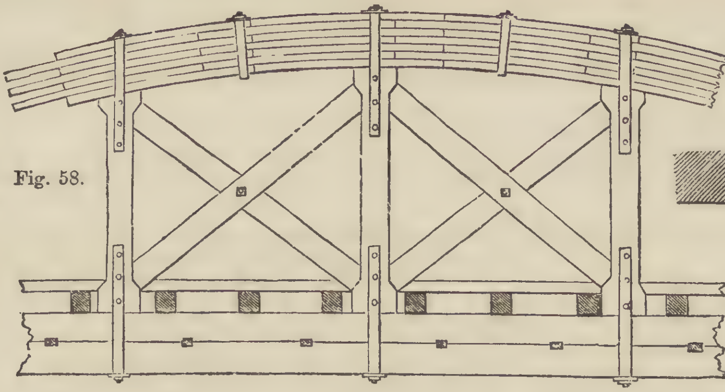


Fig. 58.

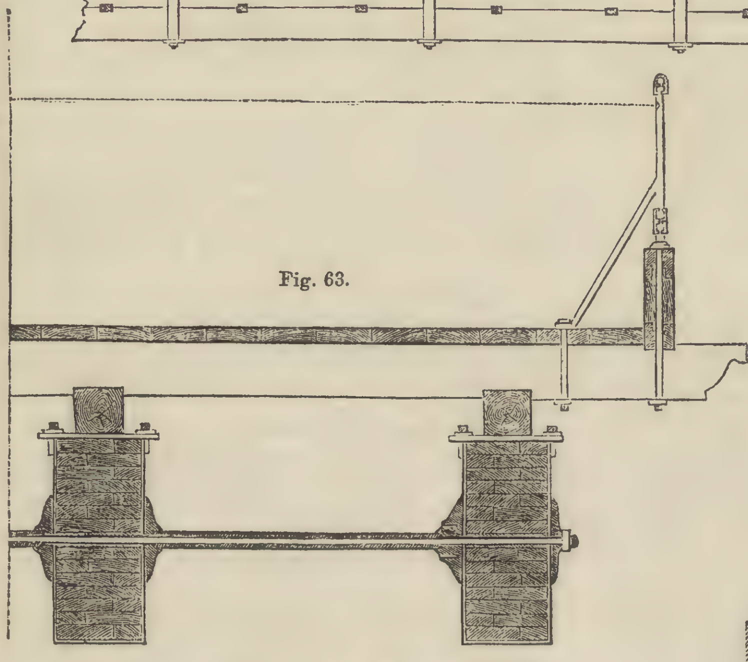


Fig. 63.

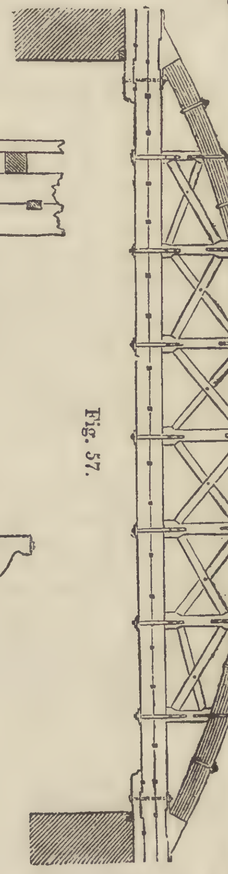


Fig. 57.

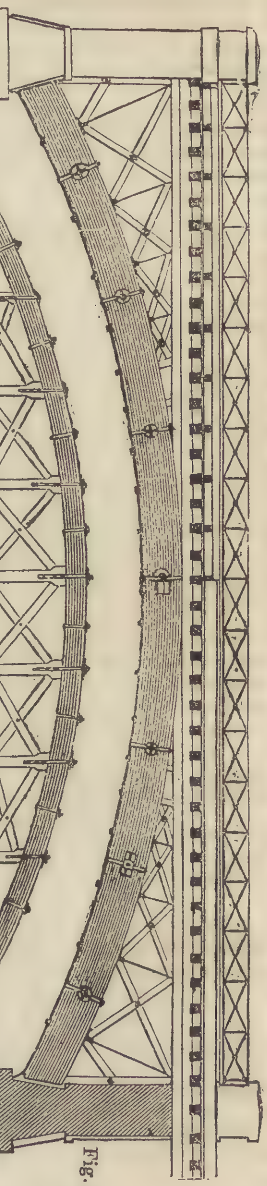


Fig. 59.

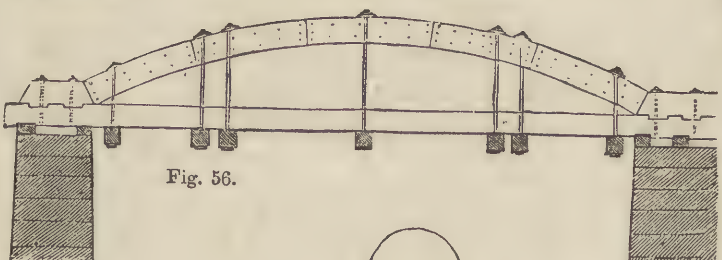


Fig. 56.

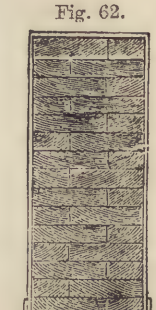


Fig. 62.

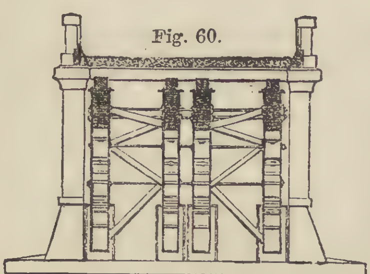


Fig. 60.

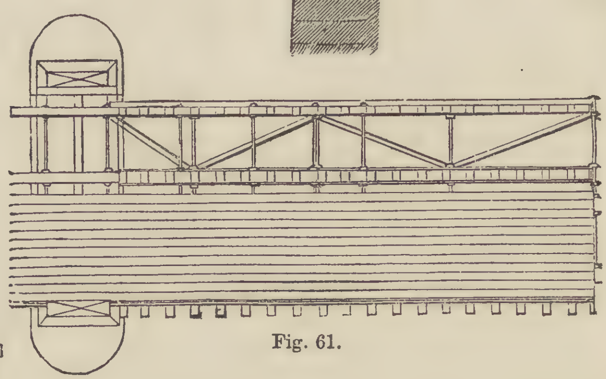


Fig. 61.

the drawing on a scale half as large again as Fig. 58. In both of these cases great care will be necessary in drawing the parallel arcs, and the student is reminded of the purpose of the joint in the inking-leg of the compass—namely, so that by bending the leg both nibs may touch the paper, and thus roughness of the edge of the line may be avoided. The lengthening bar will also be needed, and it is then advisable to hold the steel end of the compass in its place with the left hand whilst describing the arcs with the right, for the instrument, thus lengthened, becomes rather unwieldy, and the point is then liable to slip out of the centre.

Fig. 59 is the elevation, Fig. 60 a section, and Fig. 61 a half plan of one of the three arches of the wooden railway bridge from Paris to St. Germain. This bridge is supported *upon*, instead of being suspended *from*, the four arch trusses. These bows are formed of fifteen laminæ, or layers; but not only is the break-joint system carried out in the length, but in the breadth, as will be seen in the transverse section of the bows (Fig. 62). The planks of which the bows are formed are tarred, excepting on the outermost edge; and further, coarse paper saturated with tar was laid between them before binding to the template. When the required curve was attained, the planks were united by strong oak pins, plates of lead being previously inserted to prevent the wood suffering from the stress. The planks are further secured by iron bands, as in the former example. The ends of the bows abut in cast-iron shoes, firmly fixed in the springings of the piers.

Fig. 63 is the half section of the upper portion of this arch, showing the manner in which the four ribs are connected by iron tie-rods, the longitudinal girders, transverse bearers, the flooring, and the hand-rail.

With this knowledge as to the construction of the bridge, the student will not, it is believed, require any information as to the mode of drawing the example, and therefore will be left to apply the instruction he has received in relation to the previous studies.

Fig. 64 is the half elevation of an American timber bridge, by which the Erie Railway is carried over a span of 300 feet. The arch ribs of this structure consist of two separate bows, clamped between cross-timbers, and stiffened by struts placed diagonally.

The bows are constructed of three layers each, with extra pieces above and below at each end, all being, of course, firmly bolted together. These ribs abut against iron plates attached to the rocks, and support perpendiculars. On these rest transverse beams bearing longitudinal joists, across which sleepers are again placed for the support of the floor-joists of the road.

This construction will be best understood by referring to the section (Fig. 65), from which it will be seen that four such ribs are employed in the bridge, two of which, as in the last example, are placed close together in the middle, the whole being strengthened in a transverse direction by cross-struts.

The longitudinal joists being thus secured on the top of transverse head-pieces resting on the perpendiculars, the bows are

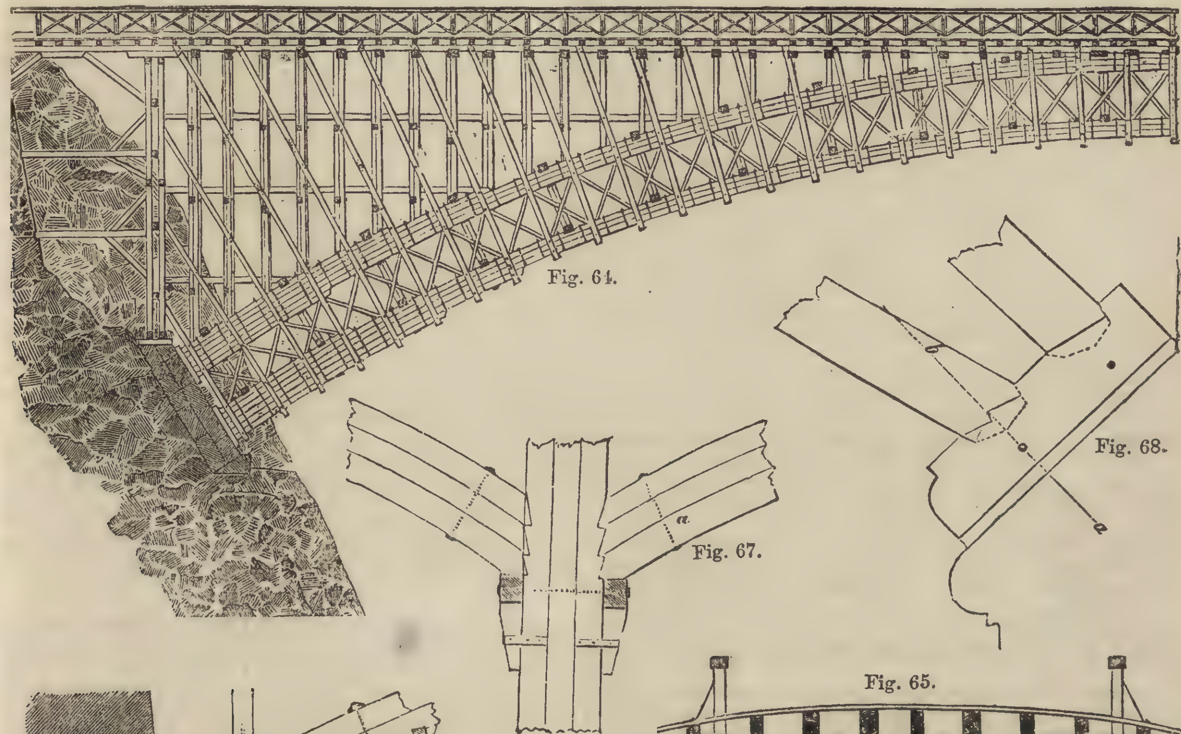


Fig. 64.

Fig. 68.

Fig. 67.

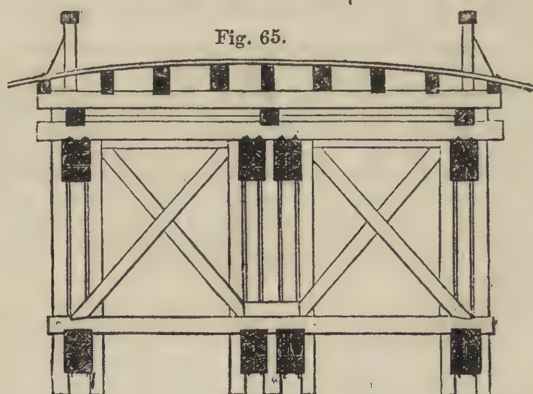


Fig. 65.

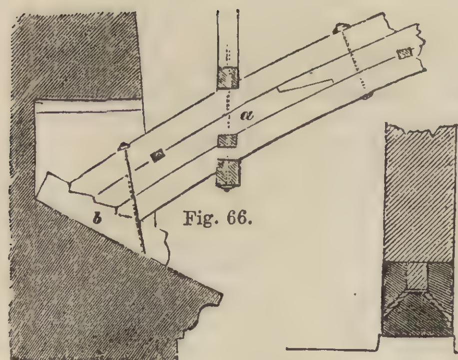


Fig. 66.

Fig. 69.

braced up to them by means of straining-pieces clamping these and all the other timbers between them. This is shown in the section, from which it will also be seen that each of the three layers in the bows is made of two timbers, placed side by side, each single bow being thus formed of six square beams in the middle, and twelve at its extremities.

This being the last study connected with bridges, the student is expected to be able to draw it without any instructions, but is advised to copy it on a much larger scale.

Figs. 66, 67, 68, with its section 69, are different methods used in the abutments of bow trusses.

MINERAL COMMERCIAL PRODUCTS.—VII.

EARTHS OF SODIUM, ETC. (*continued*).

Natron, a native sesquicarbonate of soda called *trona*, and mineral soda, is found in sandy soils in Egypt, Mexico, Hungary, etc. Large quantities are collected from the lakes of Sukena in Africa, and chiefly used for native consumption.

Borax, an important article, very useful in chemistry and the arts, is a compound of boracic acid and soda. It occurs in the waters of some lakes in Thibet and Persia, and is imported in an impure state, as *tincal*, from the East Indies. Much, however, is manufactured from boracic acid obtained in a native state by the evaporation of the mineral waters from the extraordinary volcanic lagoons of Tuscany, and from *hayescine*, a borate of lime found in Peru. The annual produce of boracic acid from Tuscany has of late years been about from 1,800 to 2,000 tons.

Saltpetre, *nitre*, or nitrate of potash, is a natural product occurring on the surface of the soil in some hot and dry countries. It can also be prepared artificially, as is done in France, Germany, and other places. The British supply comes chiefly from the East Indies, to the amount of 18,000 tons annually; the annual importation from other sources is about 5,000 tons. Besides being the chief ingredient in gunpowder, it is largely used in chemistry, medicine, and the arts.

Nitrate of soda, or *cubic nitre*, is found native in immense quantities as a geological deposit in Northern Chili and Peru, and is probably abundant over the salt plains of the same continent. It is largely imported by this country, to the extent of 50,000 tons annually (value £500,000), and used in agriculture as manure, and for many of the purposes to which saltpetre is applied.

Sulphate of baryta, or heavy spar, is a beautifully crystallised mineral, occurring in mineral veins in Cumberland, Westmoreland, Derbyshire (as cawk), Carinthia, Algiers, and Nova Scotia, and is a spurious substitute for white lead. The minerals *celestine* (sulphate of strontia) and *strontianite* (a carbonate of strontia) are used in the arts for the manufacture of the nitrate of strontia, which is employed for producing a red colour in fireworks. The salts of strontia are remarkable for the red colour which they impart to flame, whilst those of baryta give a green colour. *Fluor spar* (fluoride of calcium) is also a beautiful mineral, and important as the principal natural source of hydrofluoric acid and other combinations of fluorine. It occurs in the lead veins of Yorkshire and Derbyshire, and, from its rich colours, is used in the ornamental manufacture of tazzas of various kinds.

Sulphur is an element existing abundantly in various metallic and non-metallic compounds; but it also occurs native in quantities sufficient to render its extraction from its combinations almost unnecessary; it is, however, separated for economic purposes from iron pyrites. It is found native in all volcanic regions, either as an efflorescence on the surface or largely impregnated with earths. Sicily and Iceland possess it as a volcanic product, and from the former our chief supply, 50,000 tons annually, is obtained. Spain also supplies this substance. Sulphur is a very important article as an ingredient in gunpowder. Sulphuric acid (vitriol), so indispensable in the arts, together with other valuable sulphur compounds, has already been referred to. *Graphite*, *plumbago*, or *black lead*, although pure carbon, contains a variable quantity of iron up to a proportion of 5 per cent. It occurs in beds and embedded masses, in fissures in granitic and slate rocks, in nodules in greenstone, and, rarely, in mineral veins. This mineral, well known as the material from which the black-lead pencils of the finest quality are produced, is comparatively rare. It has been found on the right bank of the great river Tungouska, in a country previously little known. In the depths of pine-forests, and at the level of the waters of the wild Tunbusi, torn and abraded by the ice, one continuous mass of graphite has also been traced, 3,000 yards or more in length, with an ascertained depth of thirty yards. The famous mine of Borrowdale is almost exhausted. Considerable quantities are, however, procured from Ceylon (3,547 tons) and Austria (660 tons), as well as some from Spain, Mexico, Greenland, and the Cape Colony. Besides its more common uses, plumbago is of great utility in the manufacture of crucibles or melting pots for metallurgical and chemical purposes.

Among mineral productions available as articles of utility and commerce, mention must not be omitted of some that are of great use in agriculture, especially in such farming as must be carried on in densely-peopled countries, where all qualities of soil must be brought under cultivation. In addition to the silica, alumina, and lime, which are the common chemical constituents of arable soils, there must be a due supply of salts of potash, phosphoric acid, nitrogen, and some other ingredients. Organic remains, in the shape of natural vegetable decay, and of ordinary farm manures, supply these; but mineral manures are also highly valuable and much used. Limes, clays, sands, and marls are all useful under certain circumstances. Saltpetre (nitrate of potash) is a valuable addition to soils requiring nitrogen, but it is costly. The cubic nitre already alluded to exists, however, in great abundance, and is largely available for the same purpose. Phosphates of lime are used to furnish the phosphoric acid. The supply is now chiefly obtained from the small hard nodules of various sizes, composed in part of ancient organic remains (*coprolites*) which are found in the Crag of Suffolk, and in the Greensand at Farnham, Cambridge, Hitchin, Isle of Wight, Havre and other parts of France. Phosphatic nodules are also abundant in the Lias. Thousands of tons of these are annually raised, crushed, and, by the action of sulphuric acid, converted into superphosphate of lime; and they are, in this form, extensively employed as manure. Phosphate of lime is quarried in Spain, and at Sombrero, one of the West Indian isles, and prepared for agricultural purposes.

PRECIOUS STONES.

Important mineral products, on account of their great intrinsic value, are precious stones. These occur in mineral veins, and, as is the case with some of the metals and their ores, in river sands and alluvial deposits brought down from metalliferous districts. Brazil, India, the Ural Mountains, and the mining districts in general, especially those of the older formations, furnish the chief supply. Precious stones are either carbonaceous, aluminous, or silicious. The *diamond* is the only one consisting of carbon, and is well known as the hardest and most valuable gem. Diamonds are prized according to their purity and freedom from colour, or if coloured, according to the depth of the tint. Besides their extensive use for ornamental purposes, they are, in the form of fragments, of much service in the arts—as in glass-cutting, watch-making, and diamond polishing. The aluminous gems comprise the *sapphires* (the red sapphire, or Oriental *ruby*, next in value to the diamond; the blue, or true *sapphire;* the green, or *Oriental emerald;* and the yellow, or Oriental *topaz*); the *corundum*, or adamantine spar, the hardest substance next to diamond, and employed for emery-powder; the *rubies* of various reds; the *topaz* of various yellows; and the *garnets*, of which the carbuncle is the choicest. The *emerald*, of a beautiful green, and the *beryl*—yellow, blue, or colourless—are compounds of silica, alumina, and glucina. The most valuable of the silicious gems are the *amethyst*, of a purplish-violet hue; the *Cairngorm* stone, the *opal*, *sardonyx*, *agate* (which is also employed as a burnisher), *chalcedony*, *carnelian*, and *jasper*. The *lapis-lazuli*, from which ultramarine used to be prepared, is a beautiful mineral, found in China, Persia, and Siberia. The *turquoise* may be considered as a phosphate of alumina, lime, and silica, with iron and copper. The chief supply is drawn from the peninsula of Sinai, which appears to have been the great mining district of the ancient Egyptians. The turquoises, so much admired for their beautiful blue colour, occur more or less in veins of sandstone.

With this notice of precious stones we bring our brief account of the Mineral Commercial Products of the earth to an end.

AGRICULTURAL DRAINAGE AND IRRIGATION.—III.

By Prof. Wrightson, Royal Agricultural College, Cirencester.

CAUSES OF EFFICACY OF DRAINAGE—ACTION OF DRAINS ON THE SOIL—VARIOUS METHODS OF DRAINAGE—CAPILLARY ATTRACTION AND ITS EFFECTS.

In the last paper we considered the causes of the efficacy of drainage as a means of improving land. These causes may be briefly summarised as follows :—

1. Diminished evaporation, rendering the soil warmer.
2. Removal of stagnant water, allowing access to rainfall.
3. The introduction of air, and therefore of oxygen, into the land.
4. Washing of the surface by heavy rains prevented.
5. Improved texture, owing to alternate contraction and expansion of both soil and subsoil.

These causes are followed by good effects readily appreciated by landowners and occupiers. Thus increase in temperature is followed by an earlier and more abundant harvest, by the cultivation of a larger number of plant species being rendered possible, and by greater healthiness in the animals maintained on the farm. Causes 2 and 3 operate in a similar direction, and, in the phraseology of the farmer, "sweeten" the land, while the remaining two causes render manures more efficacious and lasting, and especially the last cause renders the land easier to work and more accessible to the roots of plants. The effects of drainage in improving definite areas of land, and the comparison between the advantages secured and the cost entailed, will be considered hereafter. At present it is only my wish to point out the relation between the causes that occupied us in the last paper, and those practical good effects which alone render the drainer's art valuable.

Our next consideration is the action of drains in the soil. We shall endeavour to come to a truthful conclusion as to the mode in which water is removed by drains. But, before doing so, we must carefully consider the condition of wet soils, the causes of their wetness, and afterwards the effect of introducing a means by which surplus water may be removed. Before proceeding another step, however, it is well to bear in mind that soils are exceedingly various in their textures, and that their relations to water must not be looked upon as constant and invariable. A few simple natural laws account for all the phenomena of drainage, but the action of these laws is modified according to the character of the soil and subsoil, and these modifications occasionally give rise to apparent contradictions in practice. In approaching this subject, it is also requisite to free the mind from false notions as to the action of drains. Thus, too often we hear a drain spoken of as "drawing," as though an underground channel exerted an active instead of a merely passive effect. All idea of *suction* on the part of drains must then be given up, and with it the notion of land being "over-drained." Land may, of course, be over-dry for some purposes; but supposing drains to be multiplied to an indefinite extent beneath the surface, it would be impossible for them to remove more than the *surplus* water of a field. They could not carry off that portion which the varying character of the soil allows it to hold, as a sponge holds a certain amount of water after it ceases to drip.

Soils are wet from three causes—from direct rainfall, from springs, and the soaking down of water from higher grounds. The greater part of our retentive soils are wet from the arrested descent of rain-water as it seeks a lower stratum. Springs usually occur on the sides of hills, and owe their existence to the presence of a bed of clay, or other retentive material, at a greater or less distance from the surface. When rain falls upon a porous soil it sinks in without difficulty, until it meets with an obstruction. Here it accumulates, and may be reached by boring a well down to it. Supposing, however, that this obstruction, probably clay, crops out upon a hill-side at no great distance, there you will have springs. As soon as the water rises in the natural reservoir until the lip of the basin is reached, it will overflow, and cause wetness in the land immediately beneath it. Again, water may find its way from the point at which it fell, and incommode land more or less remote by a slower soaking process, in which definite gushing springs do not occur. This is usually met with in free soils, and is defined by Mr. Bailey Denton as that moisture which is caused by water of distant and adjacent higher ground pressing up through free soils of a lower level, and which may be called "diffluent water."

Now the treatment of land wet from these three causes has given rise to two distinct methods of drainage: one in which the drainer effects his purpose by means of pipes laid at regular intervals, adapted to soils suffering from the first kind of wetness; and another in which the object of the drainer is rather to attack the source of water and cut off the supply, than to attempt to drain by regular channels at stated distances apart. The first method is identified with Mr. Smith, of Deanston; the second with the name of Elkington, who flourished in the latter half of the last century.

The principle upon which Elkington's system of draining was based will be rendered more intelligible when his practice is described. It is evident, however, that it is only under peculiar conditions of soil and subsoil that it can be effective. It is comparatively seldom that the source of wetness can be localised so as to allow of its removal by a single drain, and although such cases occur, yet, more ordinarily, land is wet because the rainfall is prevented from finding its way through the soil to depths at which it would be harmless to growing plants.

Let us, then, investigate an ordinary case. A field is wet, and requires draining. It is wet simply because the water cannot escape, and this may be due to general retentiveness throughout the mass, as is the case in clay soils; or to an obstructing bed at some little distance beneath the surface. Taking the first case, we are at once introduced to the difficult question of the action of drains in stiff clay soils. That water will penetrate such soils has been proved, as Mr. Morton has tersely observed, by the fact that they are wet. Their power of retention is, however, very great, and this is a force which, while it exists, cannot be overcome by any number of drains. Clay soil will hold, according to the experiments of Schübler, 48 pounds of water per cubic foot, and it is only the excess over this amount which would find its way into a drain. When, however, such soils are furnished with a series of underground channels, and when the work of the drainer is supplemented by deep cultivation, the character of the soil is gradually altered. The continuity of the soil is broken, air gains access, pulverisation takes place, and the altered soil becomes amenable to the ordinary rules which govern more usual cases. Vigorous treatment is, however, requisite, and no system of wide intervals between drains would be successful. The drains must be close enough to exert what Mr. Bailey Denton has termed a reciprocating effect upon one another, that is, so close that the action of one shall extend into the region of action of its neighbour. After the full effects of thorough drainage have been brought to bear upon a clay soil, the water will pass through it and find its way to the drains in the same manner, but never with the same facility, as in lighter soils. Let us, then, turn to the case of a more porous soil, wet from direct rainfall.

Here we must suppose a definite obstruction to the downward passage of water. The water tends to pass through the soil in straight lines, according to the law of gravity. It meets with the obstruction, and begins to rise upon it towards the surface. There is no limit to its rise. It may form a lake, or it may be the cause of a marsh. In other cases it will not rise to the surface, but form what is known as a "water-table" one, two, or more feet beneath.

Now this water-table, or level of supersaturation, is not the limit of wetness. Over it is a stratum of greater or less thickness, depending upon the character of the soil, wet from capillary attraction; and if this force raises water to the surface, the land requires draining. Capillary attraction may be defined as a triumph of adhesion over cohesion and gravity. When a piece of wood or metal is dipped into water and withdrawn, its wetness may be explained by the fact that the adhesion of the liquid to the object introduced is stronger than its cohesion to the remaining water it has left, or to the downward force of gravity.

A similar attraction is exerted by the soil and many familiar porous substances when placed in contact with water. The superior force of adhesion lifts a tiny column of water through the interstices of the porous material presented until the weight of the column thus lifted counterbalances the attraction of adhesion, and the limit of the force is reached.

A healthy soil should have a layer of earth at its surface a few inches in thickness, which must not be continually wet

even from water raised by capillary attraction. It will be readily seen that if such a layer does not exist, capillarity and evaporation will between them lower the temperature of the soil considerably. Growing plants will also suffer from the same causes which render saucer-watering, in the case of potted plants, objectionable. It is, indeed, a case closely analogous to saucer-watering, and the sooner it is altered the better for the crops. The question as to the height to which soils will thus lift water has been assumed and guessed at; but data of a precise kind are still needed. A few years ago I undertook a series of experiments for the purpose of throwing light upon this point, and the results obtained were as follows:—When air-dried clay or sand is placed in a tube, one end of which is immersed in water, the fluid rises rapidly, especially in the case of sand. Thus, twenty minutes after the experiment was commenced, the fine sand was wet 9 inches above the level of the water in the saucer, and seven hours after it was wet 15 inches up the tube. Clay, in a finely-powdered state, had during this time only raised water 3 and 5 inches in height, taking two tubes containing similar soils. The capillary power of the sand was, however, almost exhausted in this short period, and although the experiment was conducted for 132 days the column of water was never raised higher than 23 inches. The clay behaved very differently. Although water rose slowly, it rose very steadily, and at the termination of the experiment, 132 days after its commencement, it was wet 35 and 33 inches, taking again the results of two tubes. During the last six weeks of the experiment the rise was exceedingly slow, and only 1·8 inch of extra height was obtained. As this was partially due to the upper soil becoming wet by evaporation and condensation of water from the part wet by the force of capillarity, the limit of the force was considered to have been reached, and we may, therefore, take 3 feet as the height to which water may be raised by clay in a fine state of division. There was one more point worthy of attention in these experiments, namely, that a precisely similar soil to the clay just mentioned, but in a somewhat coarser state of division, was only able to lift a column of water 15·5 inch, showing that physical condition even more than material is an important constituent in this power possessed by soils.

It is the object, then, of the drainer to so lower the water-table that a thin layer of dry soil may intervene between the surface and the portion wet by capillary attraction.

A drain is constructed, say four feet beneath the surface, and immediately water flows from it, the water-table begins to sink, until it is on a level with the bottom of the drain, just as the water in a cask would sink to the level of the lowest portion of a hole made through the wood. Remembering that water falling on the surface makes its way down through the soil as straight as possible, it is evident that rain feeds the water-table, constantly tending to raise it; but as the water-table will have a difficulty to rise higher than the drain, it will be seen that the water, for the most part, enters the bottom, and not the top of the drain. It can only enter the top when, by heavy rains, the water-table is unnaturally raised; but on the return of ordinary weather the lowest portion of the draining tile will once more become the upward limit of the saturated portion. The area over which one drain will act is, of course, very limited, and the limits of its action are soon reached. The water-table, although kept down to the level of the drain in its immediate proximity, just as a river keeps down the water-table of a district through which it passses, yet rises as we recede from the drain until it extends to a point completely out of its influence. Hence a series of drains is required so near to each other that the level of supersaturation is sufficiently lowered throughout the intervening space. It is generally believed that the action of drains is intensified by the near proximity of other drains. This is mostly owing to the aëration of the soil. A bed of sand or gravel underlying a clay soil will not drain the field, although such a gravel bed may be looked upon as a continuous drain, or means of escape for water. Under such circumstances, however, a few drains placed at wide intervals would bring the drying power of the porous bed into immediate action by the admittance of air, and the field would be easily and effectually dried. It is, indeed, surprising to what distances drains, under such circumstances, will draw. Instances are not wanting in which the channels have been effective at sixty yards apart. Such cases at once lead us to the consideration of the means of draining employed by Elkington and other drainers, and introduce us to the more purely practical part of our subject.

BUILDING CONSTRUCTION.—V.

BRICKWORK.

Bricks may be considered as artificial stones, and seem to have been used from a very early period in the history of man. Their average size in this country is a trifle less than nine inches long, four and a-half inches wide, and two and a-half inches thick. Their uniformity in size enables builders to describe the thickness of walls by the number of bricks extending across it; thus, a slight brick partition wall being formed of bricks lying on their broad side, with their length in the direction of the length of the wall, is called a "half-brick thick," its thickness being four and a-half inches; a wall in which the length of the brick extends through the thickness is called a "one-brick thick;" a wall 14 inches through is called a "brick and a-half thick" (though to speak more accurately it would be $13\frac{1}{2}$ inches, that is, 9 for the whole brick and $4\frac{1}{2}$ for the half); an 18-inch wall is said to be a "two-brick thick," and so on.

If we suppose a wall of only half a brick thick, all the bricks used would, of course, be laid lengthwise, so as to show their whole length in the face of the wall. In laying a second course of bricks, care would be taken to prevent any two vertical joints from coinciding. This would be effected by placing the joints or meeting of the ends of the bricks forming the second course over the middle of the bricks of the course below. This arrangement would be attended to in all the succeeding courses, and is technically called *breaking joints:* a wall thus built is said to have a proper *bond*, a term which implies that the parts are well connected.

It must, however, be remarked, that the above supposition of a building only half a brick thick has been introduced merely to illustrate the principle of what is technically called *bond* in building; no brick wall so slight as the above should ever be used, this dimension being much too weak to afford proper stability even to the smallest buildings, unless the brickwork be held together by wooden framing, of which it fills the vacant spaces. This style of work, used for economy, is altogether unsuitable for public buildings, unless of a temporary nature, and is called "*brick nogging*," of which specimens are very common, especially in villages. Brick nogging is also sometimes used for the partitions of dwelling-houses.

It is important that brick walls should be kept perfectly vertical; and it must be remembered that if a wall at the bottom is in the slightest degree "out," the evil (like every other) will go on increasing, the top will gradually extend beyond the foundations and fall. But this is not all; the wall must be kept "plumb," which does not necessarily mean upright, but a straight surface; thus, a wall may be slanting, as against a bank, or the side of a tower which tapers towards the top; but in whatever position it may be, it must be kept plumb; and the plumb-rule* may not only be used for this purpose, but to keep the vertical joints regularly over each other. This is generally termed "keeping the *perpends.*" Next in importance to this, or we may say *equal* to it, is the subject of *bonding*. By *bond*, is meant that method of combining the bricks that each individual may be supported by as many others as possible; and this is done by the judicious arrangement of the joints, which will be seen on reference to the annexed illustrations.

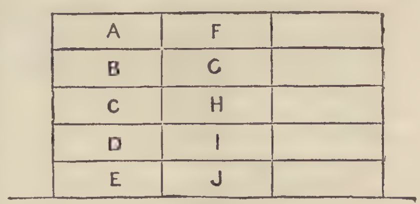


Fig. 9.

* A *plumb-rule* is a straight piece of wood, to which is attached a string with a plummet or lump of lead. The name is derived from the Latin word *plumbum* (lead), and the line formed by the weighted cord, when perfectly still, is a true *vertical* line.

Let us suppose that an attempt were made to build a wall as in Fig. 9, viz., by placing rows of bricks over each other: it will be evident that here none of the stones receive any other support than is afforded by those immediately under them. Thus A is supported by B, C, D, and E, and this is the greatest amount of support it could receive; nor would it be less liable to sink (supposing the ground to give way under it), even if it rested on a greater number of bricks so disposed, for in case of failure in the foundation, the whole column A B C D E would sink, sliding down at the side of F G H I J.

Now let us turn to Fig. 10. Here, by the simple arrangement of "breaking joint," we get the brick A supported by *two* others, B and C; these rest on *three* bricks, D, E, F; which in their turn are supported by *four*, G, H, I, J; and these again rest

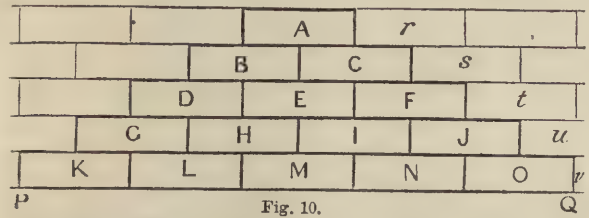


Fig. 10.

on *five*, K, L, M, N, O. Thus the brick A is supported by *fourteen* others, and its foundation rests on the entire space extending from P to Q; further, this breadth of foundation does not refer to this brick only, but to *every* individual one composing the wall: thus, *r* rests on C, *s*; E, F, *t*; H, I, J, *u*; and L, M, N, O, *v*; and any brick taken promiscuously is similarly supported; thus D rests on G, H, and G, H rest on K, L, M, etc.

In this illustration all the bricks are supposed to be laid on their broad sides, with their length parallel to the front of the wall; in this position they are called *stretchers*. When bricks are laid so that their *ends* are towards the surface, and their length extends into the thickness of the wall, as in the group shown in Fig. 11, they are called *headers*.

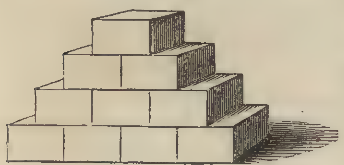


Fig. 11.

Now, on referring to the previous diagram (Fig. 10), it will be seen that the wall there represented would be a "half-brick thick" one; and that even if we were to build one three times as thick on the same system, the wall would consist of three separate ones of half-brick thickness each, *neither having any connection with the other;* and thus the front might fall forward, the

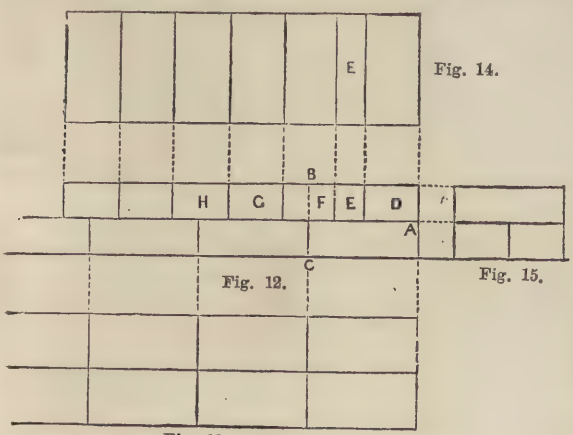


Fig. 14.
Fig. 12.
Fig. 15.
Fig. 13.

hindermost one might fall backward, or the middle one might sink; for neither one would give any support to the other, not being in any way *built* in to each other, the bonding being merely longitudinal or *lengthwise*, but no *cross* bond existing between them. Combinations of stretchers and headers have therefore been devised, by which the entire thickness of the wall is so bonded as to form one compact structure. Thus, in the one system called "English bond," one course of bricks

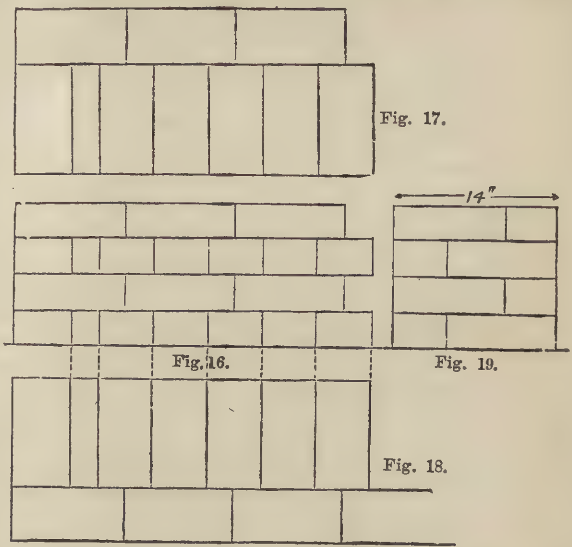


Fig. 17.
Fig. 16.
Fig. 19.
Fig. 18.

is laid lengthwise, or as stretchers; and the next crosswise, or as headers.

The annexed illustration (Fig. 12) shows the commencement of a wall of one-brick thickness, built in what is called English bond. In this it will be seen that the one course consists entirely of stretchers, and the other entirely of headers. The plan of the lower course (Fig. 13) is given below the elevation, and the plan of the upper course (Fig. 14) is placed above it.

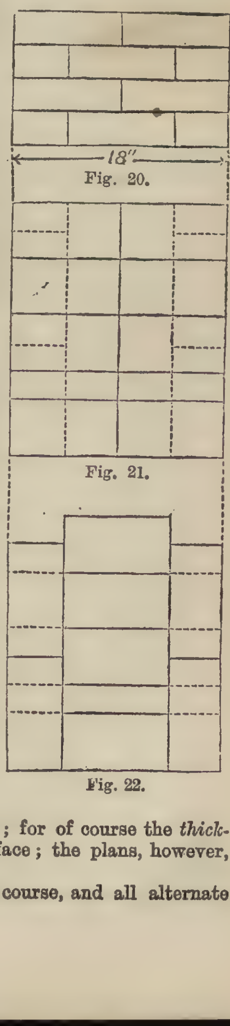


Fig. 20.
Fig. 21.
Fig. 22.

Now bricks are exactly half as broad as they are long, and thus, if when the first course of stretchers had been laid, we followed the simple idea of placing the next course as headers, and commenced at A (Fig. 12), we should not produce a bond at all, for the second header, B, would fall over the end of the first stretcher at C; thus one joint would be immediately over another; and of course, if this were carried up, one portion of the wall would soon separate itself from the other. The bricklayer, therefore, having laid his lower course, places D, his first header, at A; he then cuts a brick in halves *lengthwise*, and lays this half-brick next to the stretcher. This is called a "closer," E. He can after that proceed to lay the headers regularly, for the next header, F, will then be placed so that half of its width will be on each side of the joint C. Then will follow another header, G, which will leave a quarter of the length of the stretcher exposed, and this will be covered by the next header, H, which will overlap the joint by half its width.

Fig. 15 shows the end of the wall which has been described.

Fig. 16 illustrates a 14-inch or "brick and a-half" wall. The elevation is the same in this as in the last; for of course the *thickness* of a wall is not visible on its surface; the plans, however, show how the bonds are arranged.

Fig. 17 shows the plan of the first course, and all alternate

courses above it; in this it will be seen why the wall is called "brick and a-half."

Fig. 18 is the plan of the second course, and the alternate courses above it; and Fig. 19 shows the end of such a wall.

Fig. 20 shows the end, and Figs. 21 and 22 are the plans of a two-brick thick wall, built in old English bond, and from these it will be seen how the thickness is made up. In the

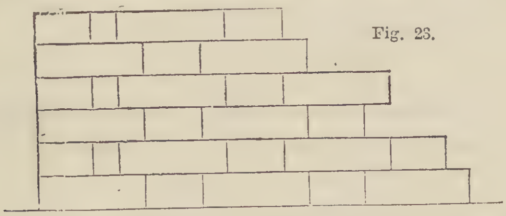


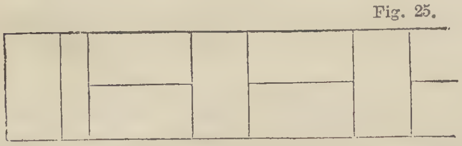
Fig. 23.

lower course, there is a row of stretchers on each side, between which headers are placed; thus the thickness is made up of the widths of two half and one whole bricks, whilst in the upper course two headers laid transversely to the face of the wall give the required width. The dotted lines on each of these plans show where the joints would fall when the one course should be worked over the other.

In copying these examples, the student is advised to work to a scale, so that the bricks and half-bricks may be drawn in their proper proportion; and it may be well to state here

Fig. 24.

Fig. 25.



that this plan is desirable in working all the exercises in these lessons; for if every line be simply measured, the studies will not convey all the instruction intended, whilst by working them to a larger scale they will afford excellent practice. The student is also advised to attempt simple colouring from the commencement, so that the use of compass, pencil, and brush may be practised together.

Another kind of bond in very general use is that called "Flemish bond."

This consists of stretchers and headers laid alternately in the same course. Fig. 23 is the elevation, and Figs. 24 and 25 are

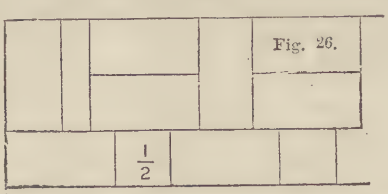


Fig. 26.

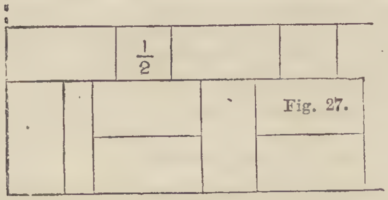


Fig. 27.

plans of two courses according to this method. It is neater in appearance than the English bond; but, owing to there being less headers in it, the cross bonding is not considered to be as strong. In walls of almost all thicknesses above nine inches it is often necessary to use half-bricks, in order not to break the longitudinal bond; but although uniformity in the bond on the surface may be thus preserved, it is at a sacrifice of the cross-tie. It must be taken as a rule, therefore, that *a brick should never be cut, if by any skill on the part of the workman it can be laid whole;* for when a brick is cut, an extra joint is created

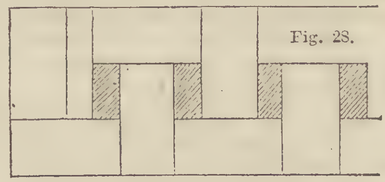


Fig. 28.

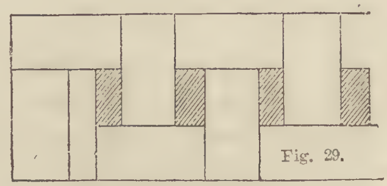


Fig. 29.

in a structure, in the erection of which the greatest difficulty arises from the great number of joints. The utmost care, then, should be taken to avoid making more than are absolutely indispensable.

Figs. 26 and 27 represent plans of first and second courses of a brick and a-half wall, built in Flemish bond.

Figs. 28 and 29 show plans of the same wall, built so as to avoid the half-bricks without interfering with the strength of the bond. This, however, leaves an open space on each side of the header in the thickness of the wall, which may either be filled up with a bat or left open.

ANIMAL COMMERCIAL PRODUCTS.—V.

III.—STEARINE AND OILS.

THE chief supply of animal oil is derived from various species of seals (order *Carnivora*, family *Phocidæ*) and whales (order *Cetacea*).

In order to meet the needs of the creature it defends, the true skin of whales is modified, forming the layer of blubber, called by whalers the blanket, probably in allusion to its office of preserving the animal heat. The blubber is composed of a number of interlacing fibres, capable of containing a very large quantity of oily matter. The thickness of the blubber varies in the several species; those inhabiting the frigid zones have it of greater thickness than those which habitually live in warmer seas. It is never less than several inches, and in many parts of a whale is two feet deep, and, moreover, as elastic as caoutchouc, offering an admirable buffer to the force of the waves and the pressure of the water, as well as a defence from cold. In a large whale the blubber will weigh thirty tons.

The species of whales that are regularly hunted for the sake of their oil are—

The *Greenland Whale* (*Balæna mysticetus*), which is confined to the Greenland and Spitzbergen seas, its migrations being regulated by the extent of the perpetual ice.

The *Hump-backed Whale* (*Megáptera longímana*) attains a length of sixty to seventy feet, and inhabits the Greenland seas, where it is found in great abundance. Though its oil is said to be superior to that which is furnished by the Greenland whale, and not much inferior to the oil of the sperm whale, yet it is not eagerly sought after.

The *Pike*, or *Finned Whale* (*Balænoptera rostrata*) is a native of the seas that wash the shores of Greenland, and is sometimes seen near Iceland and Norway. The flesh is in some repute as a delicacy among the natives of these northern regions. The oil which it furnishes is said to be particularly delicate.

Sperm Whale (*Cátodon macrocéphalus*).—This species, which measures from seventy to eighty feet in length, is chiefly notable on account of the valuable substances which are obtained from its body—oil, spermaceti, teeth, ambergris. It differs from the true whales in having no baleen plates in the

palate, but from forty to fifty conical teeth in the lower jaw, which fit into cavities in the upper, so that the mouth is capable of being completely closed. The head is of an enormous size, forming about one-third of the entire length of the animal. It is cylindrical, truncated, not composed of a bone, but of a sort of cartilaginous envelope, containing an oily fluid, which hardens by exposure to the air, and is then known as *spermaceti*. This substance is also diffused through the blubber.

The sperm whale, or cachelot, is generally distributed in all seas, but principally in those of the southern hemisphere.

The oil is obtained from the blubber, which is only fourteen inches in depth on the breast, and eleven inches on the other parts of the body, and is therefore not so abundant in proportion to the size of the animal as that which is extracted from the Greenland whale. Its superior quality, however, compensates fully for its deficiency in quantity. It is much used for burning in lamps.

The spermaceti from the head is very valuable as an ointment, and for the manufacture of candles. The United States fit out more ships than any other nation for this whale fishery, bringing home annually more than 200,000 casks of train oil, and 150,000 casks of spermaceti. Next to the United States, England is the country most engaged in the whale fisheries, the principal port, Hull, having about 200 ships. France employs 145 ships in this business, the principal port being Havre. Norway, Sweden, Denmark, and the Hanseatic Towns take some part in the whale fisheries, though not to any very great extent.

Spermaceti candles are mostly manufactured in England. Spermaceti is imported from the United States; the value per ton in 1866 was £123 15s. 6d.

The *Beluga* (*Beluga cátodon*), also called the white whale, on account of the colour of its skin, is an inhabitant of the higher latitudes, being found in great numbers in Hudson's Bay and Davis's Straits, and frequenting the mouths of large rivers on the northern coasts of Asia and America. The oil furnished by the beluga is of very good quality, although small in quantity, and is sufficiently valuable to have led to the establishment of regular beluga hunts in the great North American rivers, which they ascend for some distance in search of prey. The skin can be made into a peculiarly strong tough leather, and is said to resist an ordinary musket-ball.

The *Seals*, which have been described in page 74, are also hunted for the sake of their oil; and the pursuit of them is superseding that of the Greenland whale, for the latter has been greatly reduced in numbers by continued persecution at the hand of whalers for upwards of one hundred years past.

A large number of British vessels are engaged each year in the capture of whales and seals; and the importation of train or blubber oil from British North America for 1867 was 15,945 tuns, the average for the last fifteen years being, however, 20,000 tuns. The price per tun in 1866 was £44 11s. 10d.

Tallow.—This is an article of great commercial value. It is animal fat separated from membranous matter by fusion, and consists chiefly of stearine, with a small quantity of oleine. It is manufactured into candles and soap, and is extensively used in dressing leather, and in various other processes in the arts. We are supplied extensively with native tallow, and we annually import a large quantity, principally from Russia, Hungary, and Turkey—altogether about 30,000 tons a year. Our imports of tallow from Australia and the Argentine Confederation average also from 2,000 to 3,000 tons annually. The entire imports from all parts were—in 1865, 3,125,282 cwt.; in 1866, 3,008,807 cwt.; and in 1867, 2,419,594 cwt. respectively.

The tallow we receive from Australia is chiefly obtained from sheep, the carcases of which are boiled down for this product alone; that from South America is from oxen and even horses, which roam in a half-wild state over the grassy plains of Monte Video, La Plata, etc. The animals are slaughtered for their hides, tallow, and bones.

IV.—FOOD PRODUCTS.

Butter is extensively made in the counties of Cambridgeshire, Suffolk, Yorkshire, Somerset, Gloucestershire, Oxfordshire, and Essex. In Scotland excellent butter is made in Clydesdale and Aberdeenshire. The butter produced in Great Britain is, however, insufficient for home consumption, and large quantities are imported, principally from Ireland, where it is a staple commodity; and from Holland, Belgium, the Hanse Towns, France, and the United States. The foreign imports for 1869 were 1,142,262 cwt.

Cheese is the curd of milk compressed into solid masses of different sizes and shapes, salted and dried, and sometimes coloured and flavoured. Besides our own supply of Gloucester, Wiltshire, Cheshire, and Stilton cheeses, which are the most in demand, we import a considerable number of foreign cheeses, amongst which are Limburg cheese from Belgium, Swiss cheese from Switzerland, Parmesan cheeses from Parma and other places in Lombardy, American cheeses from the United States, Edam and Gouda cheeses from Holland, and German cheeses from Westphalia. The last come to market made up into round balls, or short cylinders, under a pound weight each.

The rich flavour of Parmesan cheese is owing to the aromatic plants which abound in the Italian pastures. Stilton cheese, so named from the town in Huntingdonshire where it was first brought into notice, is the dearest of all English cheeses, the price being generally to that of Cheshire as 2 to 1, or 2 to 1¼. To produce premature decay, and consequently an appearance of age, in these cheeses, the manufacturers are said to bury them in masses of fermenting straw; also to spread the curd out on the ground over night, by which it becomes sooner liable to the blue mould. The quantity of cheese of all kinds imported during the year 1867 was 905,476 cwt., the principal countries which supplied us being Holland and the United States.

Lard.—The melted fat of swine is imported chiefly from the United States. In 1867 we received 246,839 cwt., of the average value of £3 9s. per cwt.

LIVE STOCK.

Oxen.—The numbers imported were—in 1865, 283,271; in 1866, 237,739; in 1867, 177,948 respectively. The average price per head in 1867 was £17 19s.; and the principal countries whence imported were Schleswig, Holstein, and Holland.

Sheep and Lambs, principally imported from Holland, amounted, in 1865, to the number of 914,170; in 1866, 790,880; in 1867, 540,326, of the average price per head, in 1867, of £2 10s.

MEATS.

Bacon and Hams.—The imports in 1863 were as much as 1,877,813 cwt., since which year the importation has been on the decline; in 1867 the number of cwt. was only 537,114, of the value of £1,391,779. The greatest supply was from the Hanse Towns and the United States.

Beef (salted).—The imports, chiefly from the Hanse Towns and the United States, were, in 1867, 246,767 cwt., of the value of £623,392,

Pork (salted), not including hams, is imported from the Hanse Towns and the United States; the quantity which was received in 1867—150,285 cwt., of the computed real value of £351,871—is much below the annual average.

Preservation of Meat.—How to meet the growing demand for butcher-meat, consequent on an increase of population and a decrease of stock, arising in great measure from pasture-lands being brought under tillage, is a question of grave importance in relation to the commercial prosperity of this and other countries, and calls for the earnest attention of legislators and scientific men. Though the stock of sheep and cattle raised in England is large, and that of cattle in Ireland and Scotland is a source of wealth to those two countries, yet enormous quantities of meat are imported. When we turn our attention to Australia and the Argentine States, we find the flesh of cattle and sheep sacrificed for other parts of the animal; and he who shall devise a method by which these meats can be economically imported into this country will be hailed as one of the greatest public benefactors of the age. The importation of the living animals seems out of the question, notwithstanding the arrival of one or two cargoes; and as the jerked or sun-dried beef, though brought in at low rates from Monte Video, etc., has not found favour, there only remains the discovery of a process by which the meat can be preserved in a fresh state a sufficient length of time to admit of its transportation from regions so distant.

This art of preserving meat is one of modern times, and differs entirely from the old and common methods by means of salt, saltpetre, sugar, etc. These substances, when in solution,

do not absorb oxygen, and therefore they prevent decomposition. The history of the art of preserving meat in a fresh state is associated with the earliest Arctic explorations. Scientific observers found that scorbutic diseases arising from living exclusively on salt meat were fearfully aggravated by extreme cold; the Admiralty, therefore, offered inducements to merchants to devise plans for preserving unsalted meat, cooked or in a raw state, thus doing away with the use of salt meat altogether. It is hardly possible to over-estimate the importance of this subject, as is evident from the fact that preserved provisions, cooked or raw, are an absolute preventive of sea scurvy.

M. Appert, a French gentleman, was the first to succeed in the attempt to preserve unsalted or fresh meat, and in 1810 he received a prize of 12,000 francs from the Parisian Board of Arts and Manufactures. In the following year, M. Durant, a colleague of M. Appert, took out, in this country, a patent, which was subsequently purchased by Messrs. Donkin, Hall, and Gamble, for £1,000.

M. Appert's process consisted in partly cooking the meat, placing it in a glass vessel in a bath of chloride of calcium, heating it to about 240° Fahr., and then hermetically sealing the lid. Appert's plan, as adopted and improved by Messrs. Donkin, Hall, and Gamble, is as follows:—Tin canisters are substituted for the glass vessels, and the meat (previously parboiled) is placed in them, with a rich gravy or soup. The lids, which are pierced with a small hole, are then soldered down air-tight, and the canisters immersed in a bath of brine or chloride of calcium, heated to boiling point. On the steam issuing from the hole in the canister lid, it is suddenly condensed by the application of a cold wet rag, and a drop of molten solder being dexterously applied to the hole at the same moment, the case becomes hermetically sealed. On cooling, the ends of the canisters are slightly concave, from the effect of atmospheric pressure, if the process has been successful; but if the ends have flattened, or become convex instead of concave, then either the case has not been properly soldered, and is not air-tight, or the meat has decomposed and liberated gases.

THE SPERM WHALE (CATODON MACROCEPHALUS).

As soon as this modification of Appert's process was made practically perfect, it was tested by order of the Admiralty, and ships were dispatched by them to the Arctic regions with an abundant supply of these meat canisters. On their return, the officers in command of the expedition reported favourably of the whole. Their value in cold climates having thus been clearly demonstrated, the experiment was tried with equal success by vessels trading in the tropical regions. For ship use these preserved meats are invaluable, and hardly a vessel now leaves this country without a supply. In India they are extensively used as luxuries in the towns, and as necessaries in the remote districts, where fresh meat of any kind is scarce and bad. It may be noted here that most of the ocean steamships belonging to ports of the United States and Europe are provisioned with fresh meats conserved in ice.

V. WOOL.

In commercial phraseology the term "wool" is applied to the hair of the alpaca, goat, beaver, and rabbit, and to allied substances; but, more strictly speaking, it belongs to the sheep alone, the hair of which, from time immemorial, has been woven into cloth.

Wools are divided into two great classes—clothing wools and combing wools, or short wools and long wools; and the fabrics woven from them are termed woollens or worsteds, according as the one or the other is employed. The fibres of clothing wools felt or interlace with one another, forming thereby a dense compact material, suitable for warm and heavy clothing; these wools are manufactured into broad cloths, narrow cloths, felt for hats, blankets, carpets, serges, flannels, and tartans. Combing wools, on the contrary, though long in fibre, do not felt, and are therefore employed in the manufacture of light and loose, but still warm garments—such as stuffs, bombazines, merinos, hosiery, camlets, and shawls, and various mixed goods, as damasks, plushes, and velvets.

The wool of the sheep has been greatly improved since the animal has been brought under the fostering care of man. The *mouflon*, which is considered by some zoologists as the parent stock of the common domestic sheep, inhabits the mountains of Sardinia, Corsica, Greece, Barbary, and Asia Minor. This animal has a very short and coarse fleece, more like hair than wool. When domesticated, the rank hair disappears, and the soft wool around the hair-roots, which is hardly visible in the wild animal, becomes singularly developed. If sheep are left to themselves on downs and moors, there is a tendency to the formation of this hair amongst the wool; its occurrence in the fleece of domestic sheep is therefore rare, and is always regarded as proving defective sheep-farming.

The climate of this country is unfavourable to the growth of the best wools; hence the superiority of the Merino, Saxony, and Australian wools, the produce of countries having a higher average temperature.

THE STEAM-ENGINE.—II.

By J. M. Wigner, B.A.

SUPERHEATER (*continued*)—LOCOMOTIVE BOILERS—ARTIFICIAL DRAUGHT — CONSTRUCTION OF BOILERS — MANHOLE — BLOW-OFF COCK—GAUGE GLASS, ETC.

In some forms of superheater the steam passes through a set of pipes arranged in a chamber, through which the smoke and heated air pass on their way to the chimney. In other varieties the smoke is made to traverse a series of small tubes, while the steam passes outside them. This plan was adopted in the *Great Eastern* steamer, the steam-pipe opening into a large rectangular chamber, placed at the foot of the chimney, and traversed by a large number of vertical tubes through which the smoke had to pass. The area of the superheater varies, of course, very considerably; but a common proportion is about one and a-half square foot of surface for each nominal horse-power of the engine. A somewhat similar arrangement is sometimes made in tubular boilers, vertical tubes being introduced,

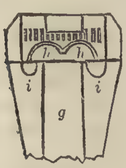


Fig. 6.

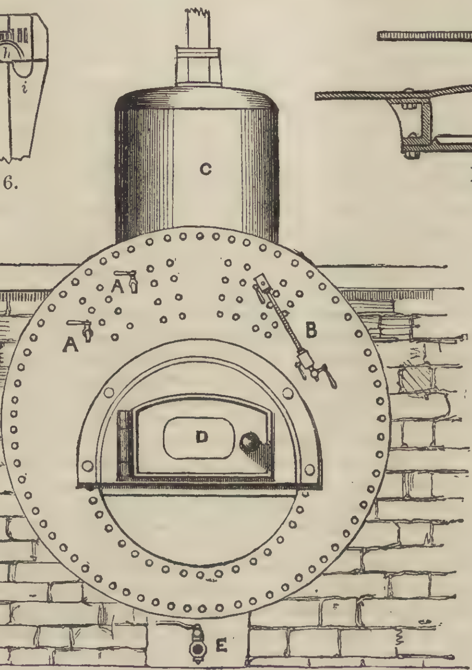


Fig. 10.


Fig. 7.


Fig. 8.

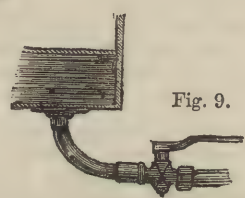


Fig. 9.

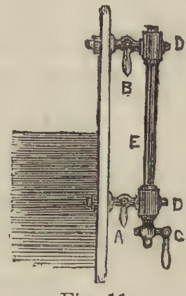


Fig. 11.

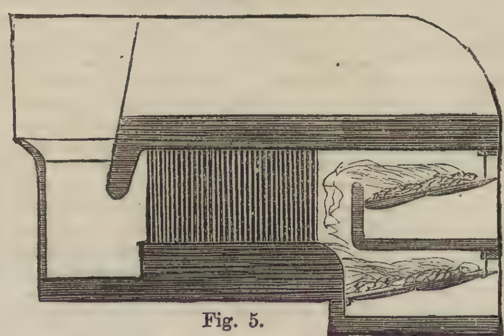


Fig. 5.

which are filled with the water, while the smoke finds its way between them, and thus imparts its heat to their outer surfaces, instead of their inner surfaces, as is usual.

This plan was suggested by the Earl of Dundonald, and in Fig. 5 we have an illustration of its use. This figure shows a section of the boilers of the *Atlantic* steam-ship. Two furnaces are employed here, one being placed above the other; the smoke from the two unites, and, after passing in and out among the vertical tubes, strikes against the bridge at the further end, and thence escapes into the chimney.

We must not stay here to notice the many other modifications often made in various marine boilers; for these, and all other details, the practical student should consult Bourne's various works on the subject, in which he will find almost every variety figured and described, and in many cases full details as to dimensions and heating surface, for the particulars of which we cannot find space.

Locomotive boilers differ in some respects from any of those already described. Instead of being built and fixed in a given place which they are permanently to occupy, they are, as their name implies, portable. The special requirements of the case demand, therefore, that they be made of small dimensions, and as light as practicable. Economy of fuel, though still an important point, is, in these, subservient to economy in space and weight. A cylindrical tubular boiler is accordingly employed; but the tubes are made of smaller diameter and greater length than those ordinarily adopted, their usual diameter being about two inches, while in length they often run from ten to twelve feet. The number employed, too, is very large; in some powerful engines as many as 300 will be found, and in this way a large heating surface is obtained without unduly increasing the dimensions of the boiler.

There is one difficulty produced by the employment of so many small tubes, the draught is considerably diminished; and as a locomotive engine is obliged to have a very short chimney, no increase can be produced in this way. It is necessary, therefore, to resort to some other means of producing a draught sufficiently powerful to maintain the necessary heat in the furnace, and the way in which this is usually accomplished is by placing at the base of the chimney a steam-pipe, the blast from which quickens the draught to the required extent.

This pipe should be fitted with a funnel-shaped mouth-piece, as in this way a much larger body of air is thrown into motion by it. There is usually a small pipe fitted to this, so that when the engine is at rest, or getting up steam, a small stream may be allowed to escape. When the engine is in action, the waste steam from the cylinders, which escapes at a considerable pressure, is commonly employed, and this it is which produces the series of puffs which may so frequently be observed issuing from the funnel of a locomotive. The draught produced in this manner is so strong that sometimes small pieces of ash or cinder are drawn from the furnace and thrown out of the funnel. These are, of course, very dangerous, and in dry weather crops have thus been set on fire; a screen is therefore employed to intercept them, and let them fall down to the foot of the chimney.

In American locomotives the top of the funnel is usually considerably enlarged, and fitted with a contrivance known as a "spark-trap" or "spark-arrester." This is more necessary there on account of the prairies, which in a dry season are very easily fired, and also because wood is often burnt, and this throws off more sparks than coal does. The details of this trap will easily be understood by reference to Fig. 6. The two inverted curves, *h h*, placed above the central funnel *g*, arrest the sparks, and throw them down into the chambers, *i i*, where they remain, while the smoke and hot air escape through the shaded apertures.

Coke alone ought to be burnt in locomotive boilers, so as to prevent the smoke which is often produced in considerable quantity; but this regulation is by no means rigidly adhered to, and often dense volumes of smoke may be seen issuing from the funnel. The furnace-bars are usually placed so as to slope considerably, and by carefully introducing the coal in front it becomes coked, the smoke given off being mixed with the air and partially burnt in the further part of the furnace; but even with this precaution a good deal of smoke is often given off when coal is employed.

Locomotives for use in countries where wood is plentiful and cheaper than coal, are made with special furnaces for burning wood. The main difference consists in the necessity for an increased area of heating surface, as the heat produced is less than where coal is employed. In an ordinary locomotive about five square feet of heating surface per nominal horse-power is the usual allowance.

The following details of a locomotive passenger engine, exhibited by Messrs. R. Stephenson and Co. at the Paris Exhibition in 1867, will give a general idea of the dimensions of ordinary passenger locomotives. Goods engines are, of course, made much heavier and more powerful, speed being in them of much less importance than tractive force.

The diameter of the cylinders was 16 inches, and the length of stroke 22 inches. The heating surface of the firebox was 83 square feet, and in addition to this there were 161 tubes, 2 inches in external diameter and 11 feet 4 inches long, presenting in the aggregate a heating surface of 960 square feet. The boiler was 4 feet in diameter, and might be safely worked up to 190 pounds pressure per square inch, being made of ½-inch boiler plate. The driving-wheels were 6½ feet in diameter, and sustained nearly one-half the weight of the engine, which was about 30 tons.

There are many general features common to nearly all forms of boilers, to which we must now turn our attention, for at present we have mainly been concerned with the shape and arrangement of the various parts. Copper has occasionally been employed as the material of which they are constructed, and in many respects it is the best material, as it is less liable to become incrusted with the deposit from the water, and is also more durable than iron. The greatly increased expense, however, precludes its adoption, and boilers are almost universally constructed of wrought-iron plates. The best plate-iron should be chosen for this purpose, and it should be very tough, so as to withstand the pressure. The plates are cut so as to overlap one another to a slight extent, and, after being bent to the proper curvature, are firmly riveted together in the manner shown in Fig. 7. The holes should be very carefully punched or drilled, so as to be just the same distance apart in the two plates; if this is carelessly done, so that the holes do not exactly correspond, and the plates have to be forced together by "drifts," and then riveted, the strength of the boiler is much impaired. When the plates are brought together they are temporarily secured, and then a rivet is inserted in each of the holes. The rivets, which should be of the best Lowmoor iron, are first heated in a furnace till they are quite soft; they are then inserted, and immediately hammered down so as to form a good and solid head. As it cools and contracts the rivet draws the plates closer together, and thus forms a tight joint without any packing being introduced. The rivets should be placed at distances of about two inches from centre to centre.

When the boiler is completed, the joints are carefully caulked —that is, the inner edge is forced into closer contact by means of a hammer and cold chisel or punch, and before being used it should be tested by forcing cold water into it till the pressure exceeds that to which it will ever be subjected when at work. Any leak will thus be easily detected. Rings of well-made angle iron are placed round the ends, and also at intervals along the length. Internal stays or struts are also introduced wherever they are considered necessary, to guard against the boiler bulging or collapsing. The different plates should be so arranged that the seams do not form a continuous line either round or along the boiler, each being intermediate to those in the adjoining plates. The reason of this is that the plates become somewhat weakened by the rivet-holes, and the boiler might under pressure part at the seams.

The thickness of the plate-iron employed depends upon the pressure at which the boiler is to be worked, and also upon its diameter. The following is a rule which will give the minimum thickness of plate that ought to be employed, and it is, of course, better to be on the safe side, and exceed rather than fall short of this:—

Multiply the internal diameter of the boiler expressed in inches by the maximum pressure in pounds per square inch of surface, and divide the product by 8,900; the result will give the thickness of the plate in inches.

An example will render this more clear. Suppose we have a boiler whose diameter is 4 feet, and it is required to work it to a pressure of 70 pounds, what thickness should the plate be? Multiplying 48 by 70 we get the product 3,360, which, divided by 8,900, gives us ·377 as the thickness required.

The usual thickness of the plate employed is about three-eighths of an inch, and the rivets have a mean diameter of about five-eighths of an inch, though they vary more or less from this. The plates to which the tubes are fastened in tubular boilers are made considerably thicker, as the number of holes drilled in them materially lessens their strength. For the same reason, whenever an opening is cut in the boiler to admit the steam-pipe or any other fitting, it is well to rivet an internal block round the opening, so as to compensate for the diminished strength. As a result of many experiments, it is found that the tenacity of boiler-plate increases with the temperature up to about 500° or 600° Fahr., but beyond this it diminishes.

In every boiler it is necessary to provide some opening sufficiently large to enable a man or boy to get inside, in case of any repairs being necessary. This opening is known as the "manhole," and must be so arranged that it can at pleasure be closed so as to be perfectly steam-tight. The plan for a long time adopted was to cut an oval hole in the boiler, and procure a plate about an inch or two larger on each side. This could be inserted sideways through the opening, and the edge being smeared with red lead or some similar substance, it was held in its place by means of a screw fixed to it, which passed through a hole cut in a movable arch, placed outside the boiler over the opening. By screwing the nut on the screw, the plate was drawn tightly against the boiler; and the pressure of the steam being exerted outwards, aided in keeping it firm in its position.

This plan has, however, gone almost out of use, and manholes are now constructed on the plan shown in Fig. 8. A circular or oval aperture is cut in a convenient portion of the upper surface of the boiler, and a short tube with a flange at the lower end, so made as exactly to fit the curvature of the boiler, is fitted on over the opening. This tube is securely fastened to the boiler by means of screw-bolts and nuts; packing is also introduced to render the joint tight. On the upper end of the tube is another flange, made quite true, so that a thick plate of iron may be firmly bolted to it, and close the opening steam-tight. Copper wire is sometimes employed in this case as a packing, a ring of it being laid on the surface of the flange, and as the screws are tightened the wire becomes flattened, so as to give a very perfect joint, and one not likely to become injured by the heat.

In addition to this opening, another is required to enable the boiler to be emptied when necessary. The water used often contains a large amount of various mineral salts in solution, and as these cannot pass away with the steam, the water in the boiler becomes so saturated that it deposits a portion as a crust on the internal surface. It is therefore advisable occasionally to let a considerable portion of the water in the boiler escape, and this may be effected by opening this blow-off cock, as it is termed. (Fig. 9). At a convenient portion of the under-side of the boiler an opening is made through the plate, and one end of a large pipe is inserted in this, the other end being closed by a valve able to withstand the pressure of the steam. This valve has a square spindle, and is usually situated just in front of the boiler, or in the ashpit, so that it may easily be got at when required, without being in the way under ordinary circumstances.

Were the boiler left quite unprotected externally, a very large amount of heat would be lost by radiation from its surface, and the building in which it was placed would soon become extremely hot. To guard against these inconveniences, the boiler should be surrounded by some material which is a bad conductor of heat, and which will therefore prevent its escape. For this purpose sawdust is found to answer very well indeed.

In many cases, therefore, the boiler is surrounded with a casing or "lagging" of wood stuffed with sawdust, and when this is done the boiler-room will be quite cool.

The steam-pipes and the cylinder of the engine are frequently jacketed in a similar way. Patent felt and various fibrous substances are in some cases employed in place of sawdust, and answer the same end. In locomotive boilers some protection of this kind is very necessary, since they are so much exposed to the air and weather that the loss of heat would be very large and serious. An incidental advantage of casing the boilers is that when protected they may be touched with impunity, and thus many burns are avoided.

If we examine any boiler we shall find several appendages affixed to various parts: these we must now describe. When a boiler is started it is filled with water up to a certain fixed level, and it is very important that this level should be maintained almost uniform.

The flues are so arranged that no portion of the boiler-plate or tubes shall be exposed to the direct action of the heated air, unless it is protected by being covered inside with water. Some of this water, as soon as the temperature rises, becomes converted into steam, and thus keeps the plate from becoming unduly heated. If now the level of the water falls too low, a portion of the surface will be exposed, and may not improbably be injured by being overheated, and thus rendered so soft as to bulge. Many explosions have arisen from this cause, and the need of great care will therefore be easily seen. As the engine is at work, a portion of the water is converted into steam, and thus the level inside the boiler is continually falling: we want, therefore, some easy mode of indicating at all times the exact level, and also of introducing fresh supplies of water to take the place of that evaporated.

The simplest mode of indicating this is by means of a "water gauge," which is shown fixed on the end of the boiler at B (Fig. 10). This consists of a thick glass tube communicating above and below with the boiler, so that the level of the water in the glass is the same as that of the water inside the boiler. The gauge is usually provided with cocks, as shown in Fig. 11; by means of those at A and B it may be quite cut off from connection with the boiler, so that in case of the glass becoming accidentally broken, the steam and water can at once be prevented from escaping, and a fresh glass can easily be introduced. An additional cock is placed at C, by which the water in the tube can be allowed to escape from it. The tube is usually fixed into its sockets, D, D, by a screw-ring, an india-rubber packing being introduced to render the joint steam-tight.

Another plan frequently employed for ascertaining the level of the water is to place two cocks, A, A (Fig. 10), in the end of the boiler, the one being an inch or two above the other, and the level of these is so arranged that the one shall be a little below the normal level of the water, and the other about as much above it. When, therefore, the water is at the proper height, steam should issue from the upper one when it is opened, and water from the lower one. Should it at any time fall too low, steam will issue from both, and the engineer should then immediately set the feed-pump in action, so as to introduce a fresh supply of water. If, on the other hand, water issues from both cocks, it shows at once that there is too much water, whereby steam space is curtailed, and the proper action of the boiler is somewhat interfered with.

As a general rule it is found best to have as much steam space in the boiler as is equivalent to about eight times the contents of the cylinders; in a small boiler it is well, however, to allow rather more. One disadvantage of curtailing the steam space is that the steam carries with it a larger amount of water in a fine state of division, and this is deposited in the cylinder. To guard against this as much as possible a steam dome (C, Fig. 10) should be provided, and the steam-pipe should start from its highest point.

The door by which fuel is introduced into the furnace of the engine shown in Fig. 10 is at D, while the ashpit is immediately below it. The cock at E shows the appliance by which the quantity of water in the boiler can be reduced at pleasure, or by which the boiler may be emptied when necessary. This cock, and the manner in which it is affixed to the boiler, is shown on a larger scale in Fig. 9.

The description of the arrangements usually employed for injecting water into the boiler we must defer to our next lesson.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

IV.—JAMES TAYLOR.

BY JAMES GRANT.

James Taylor, generally understood to be the first person who applied the power of steam to inland navigation, was born on the 3rd of May, 1758, at Leadhills, a Lanarkshire village, which is perched amid a complete wilderness of dismal and heathy mountains, the most sterile and bare perhaps in Scotland. This victim—for such he proved to be—of a life of disappointments received the rudiments of his education at the academy of Closeburn, in Dumfriesshire, a free school, which was handsomely endowed by a gentleman named Wallace in 1723. Isolated though his native village is still, it has possessed a good library since 1741; and of the contents of its volumes young Taylor is said to have amply availed himself. After graduating in medicine, he was employed by Mr. Patrick Miller, of Dalswinton, as tutor to his two sons, who were studying at the University of Edinburgh. It was the wish of Mr. Miller that Mr. Taylor, whose scientific attainments had been warmly praised by a mutual friend, should assist him in certain mechanical pursuits, with which he was in the habit of amusing his leisure hours; and in the year mentioned, he happened to be engaged in a series of operations for adding paddle-wheels to sailing-ships, with the view of rendering them independent of wind and tide, so that they could be enabled to avoid currents or lee-shores, and extricate themselves from various perilous positions—somewhat of the old Archimedean idea of machinery driven by human agency. Taylor, who had a strong love of mechanics, entered warmly into the idea, and aided his patron in the construction of a double vessel, sixty feet long, having intermediate paddles which were revolved by a capstan that was worked by human labour; and this craft they launched and tried with success on the waters of the Forth in the spring of 1787, and easily succeeded in distancing a smart custom-house vessel which was contented to sail under canvas.

The success of this attempt convinced Taylor of the great utility of paddles; but perceiving that the crew at the capstan soon became exhausted, he conceived that some superior mechanical labour was necessary to render their invention of value to the nautical world. After much thought, he wrote to Mr. Miller on the subject, and received a reply which showed that their ideas were similar. "I am of the same opinion," he wrote, "and *that power* is just what I am in search of. My object is to add mechanical aid to the natural power of the wind, to enable vessels to avoid and to extricate themselves from dangerous situations, which they cannot do on their present construction." The letter concluded by requesting him to suggest some plan calculated to accomplish this purpose. Mr. Taylor applied himself to a close consideration of all the mechanical powers already in use, but failed to be convinced of the possibility of applying any of them to this new purpose, till at length the steam-engine presented itself to him.

This idea was not entirely new, for though Taylor may never have heard of Blasco de Garay, a Spanish merchant captain of that name, in the year 1543, during the reign of the Emperor Charles V., conceived the idea "of an engine able to move large vessels in calm weather, without the use of oars or sails;" and this engine he actually tried on board of a 200-ton ship named *La Trinidad*, in the harbour of Barcelona; but all we know of it is, that it consisted of a boiler, and an axle laid across the vessel's deck, with a wooden wheel at each end—and that somehow it proved a failure eventually.

On suggesting the adoption of the steam-engine to nautical purposes, Taylor found that he excited in Mr. Miller more astonishment at the novelty than respect for the feasibility of the plan; but though somewhat startled himself at the boldness of his own conception, he was, nevertheless, convinced of its being perfectly practicable.

Though well skilled in mechanics, Mr. Miller made many objections, some of which were on the score of expense and risk, thinking that steam-power would be unavailing in those critical circumstances which it had been his chief project to obviate or conquer. "In such cases," he wrote, "as that disastrous event which happened lately, the wreck of a whole fleet upon a lee-shore off the coast of Spain, every fire on board must be extinguished.

and of course such an engine could be of no use." But Taylor had thoroughly considered the subject, and, undaunted by obstacles, urged that, if inapplicable to sea-going vessels, the new motive power might at least prove useful on canals, estuaries, and inland lakes. After long consideration, Mr. Miller consented to assist him in the matter, and asked him to prepare sections and other drawings to show how the engine and external paddle-wheels were to be connected. Taylor did so, and his friend, though still unconvinced that the project was possible, agreed to be at the expense of the experiment, provided the sum required was not too heavy, as he candidly confessed that of the power of steam he knew nothing. They were then in the country, at Mr. Miller's mansion of Dalswinton, and it was fully arranged that on their return to Edinburgh in winter, the engine was to be constructed. During the summer of that year Mr. Miller had drawn up an account of all his experiments upon shipping, and, at Taylor's suggestion, introduced an allusion to steam as an agent probably to be employed in the propulsion of his vessels; and copies of this work were transmitted to the King, the Ministry, to the leading members of the Upper and Lower Houses, the President of the United States of America, and to all the maritime powers of Europe.

In the winter of 1787, when Mr. Miller had returned to the Scottish capital, he empowered Mr. Taylor to set about the construction of the intended engine; and the latter employed a young engineer named Symington, who was then residing in Edinburgh for the study of mechanics, and who had already attempted some improvements on the steam-engine. After long discussion, it was agreed that the latter should form it on a plan of his own, and that the great experiment should be made almost privately, in the ensuing summer, on the Loch of Dalswinton, in Dumfriesshire. Several months were occupied in the construction of the engine, to see after which Mr. Taylor remained in town, while his patron and pupils returned to the country. At length, to his joy, it was completed, and he proceeded with Symington to Dalswinton, where, on the 14th of October, 1788, the great experiment was made. The event had been noised abroad, however, and on that day the beautiful little lake which lay on Mr. Miller's property was surrounded by a great crowd of spectators. The vessel built for the purpose was a double one, and the engine, which was furnished with a four-inch cylinder, was placed in a species of framework on the deck, and the experiment, which was ultimately destined to effect such a revolution in nautical matters, proved a perfect success. The little vessel moved at the rate of five miles an hour, and the connection between the engine and the paddles was free from all clumsiness; while it also appeared that all dread from the introduction of a furnace into a structure so inflammable as a wooden ship could be obviated. For several days the experiment was repeated, and thus the first steamship continued to traverse in safety the little inland lake, to the wonder and delight of all who came to see her; and a full account of his invention, or adaptation of steam to seafaring purposes, was drawn up by Mr. Taylor and inserted in the *Scot's Magazine* of the following month. Before applying for a patent to protect their joint invention, Messrs. Taylor and Miller deemed it necessary to test it more fully, by its application to a vessel of a larger size; and the former, accompanied by Symington, had one constructed at the Carron Foundry in the summer of 1789. This craft was of considerable dimensions, and had an engine the cylinder of which was eighteen inches in diameter. Winter drew near before she was completely fitted up and launched on the Forth and Clyde Canal, in presence of the Carron committee of management, and of all who were interested in the matter.

The steam was got up, and the vessel moved smoothly for a considerable distance beyond Lock Sixteen; but on giving the engine full play, the flat boards of the paddle-wheels, which had been too slenderly constructed, broke, and put an end to the voyage. Re-constructed on a stronger principle, she made a second trip on the 26th of December, when she attained seven miles per hour; and a full account of the invention, written by the future Lord Cullen for the Edinburgh newspapers of 1790, brought it prominently before the country as a new means for extending inland navigation. But here for a time the matter ended; for Mr. Miller became so deterred by the excessive expense on one hand, and a necessity for improving his estate on the other, that he declined to proceed further with the project. He was somewhat disappointed by the extravagance of the engineer, whose expenses had gone far beyond his estimate; and Taylor was quite unable personally to prosecute the scheme so auspiciously commenced. Our Government ignored the inventor and the invention; and Mr. Fergusson, younger, of Craigdarroch, pitying his disappointment, sought, but in vain, to engage the interest of the Emperor of Austria on the subject.

The sudden indifference of Mr. Miller, the attention of the public to the war of the French Revolution, and the obscure position of Taylor, who was himself unable to do anything—his pecuniary means being most limited—all combined to throw the steamboat into abeyance, and for several years it was forgotten by all but the bold projector, who for some time was thankful to find employment in superintending the working of coal, lime, and other minerals on the estate of the Earl of Dumfries.

Eleven years after the second steamer had been permitted to rot at the Carron, Symington, who had commenced business at Falkirk, constructed a third, called the *Dundas*, on the old plan, and tried her on the Forth and Clyde Canal; but the company prevented her being set in motion again, as her paddles proved injurious to the banks; so she, too, was laid up at Lock Sixteen, where she lay forgotten for several years more, though Lord Stanhope, in 1790, had been in communication with Mr. Rennie as to the best mode of applying this novel power, and in that year actually took out a patent for the propulsion of ships by steam. But his plan, though ingenious, was never put in effect, his paddles being placed under the vessel's quarter, and made to open and shut like the feet of a duck. Symington was in treaty with the Duke of Bridgewater to introduce steam on his grace's famous canal, and six boats on his supposed plan—utterly ignoring Mr. Taylor's—were ordered; but the duke's death caused the abandonment of the scheme. Mr. Fulton from America, and Mr. Henry Bell from Dundee, now came to Carron and inspected the *Dundas*, and the result was that in 1807 the former gentleman launched a steam-vessel on the Hudson, and in 1812 Mr. Bell placed another on the Clyde, each being the first vessels of the kind used for public service in the new and old hemispheres. "Thus, after all the primary difficulties of the invention had been overcome—when the barque was ready, as it were, to start from the shore, and waited only for the master to give the word—did two individuals, altogether alien to the project, come in and appropriate the honour of launching it into the open sea!"

On finding that the credit of this important invention, which was his own undoubtedly, was now assigned to others, Taylor lost neither time nor opportunity in asserting his claims. He urged Mr. Miller of Dalswinton to move in the matter, but without success. He kept his own name, however, before the public eye, and on finding that Symington had actually secured a patent, forced him into agreements of sharing the profits, which, however, were never realised. Taylor's pecuniary circumstances were far from prosperous, and when the mighty importance of steam navigation to the world at large became fully established and understood, his friends urged that he should solicit some reward from Government. In 1824 a statement of his invention and his claims was printed and addressed to Sir Henry Parnell, the chairman of a select committee of the House of Commons on steamboats, in the humble hope that his narrative might procure him some remuneration in his old age, for the benefits he had conferred on mankind in general and his country in particular; but poor Taylor prayed in vain. Not a penny was ever accorded him. Broken in health, crushed and soured by disappointments, and oppressed by penury, this ingenious but unfortunate inventor died on the 18th of September, 1825, when verging on his seventieth year.

ANIMAL COMMERCIAL PRODUCTS.—VI.

WOOL (*continued*).

MERINO wool is obtained from the migratory sheep of Spain, a breed which is distinguished from the British by bearing wool on the forehead and cheeks; the horns are large, ponderous, and convoluted laterally; the wool is long, soft, and twisted into silky-looking spiral ringlets, and is very superior in its fineness and felting properties. Its closeness and a luxuriant supply, from the glands of the skin, of yolk or natural oil,

which serves to nourish it and mats the fibres together, render it an excellent natural defence against the extremes of heat and cold. These migratory sheep, amounting in Spain to 10,000,000, are led twice a year (in April and October) a journey of 400 miles, passing the summer in the pastures on the slopes of the Pyrenean mountains, and the winter on the plains towards the south.

The word *merino* signifies an overseer of pasture lands, and is applied to these sheep because in Spain they travel in detachments of 10,000 each, under the care of fifty shepherds and as many dogs, with a mayoral or chief shepherd at their head, and have a general right of pasturage all over the kingdom.

This celebrated breed is now reared in Saxony and in Australia, which has become one of the principal wool-growing countries in the world. In 1464 Spain imported ewes and rams from the Cotswold hills.

The Cretan or Wallachian sheep, remarkable for the enormous development and magnificent formation of its horns, possesses a fleece composed of a soft woolly under-coat, covered with and protected by long drooping hairs. The wool is extremely fine in quality, and is employed in the manufacture of warm cloaks, which are largely used by the peasantry, and which are so thick and warm that they defend the wearer against the bitterest cold to which man can be exposed.

MERINO SHEEP.

"Several of the sheep are tamed and taught to obey the signals of the shepherds; these follow the leading shepherd (for there is no driving), and the rest quietly follow them. The flocks travel through the country at the rate of eighteen to twenty miles a day, but in open country, with good pasturage, more leisurely. Much damage is done to the country over which these immense flocks are passing; the free sheep-walk which the landed proprietors are forced to keep open interferes with enclosure and good husbandry; the commons, also, are so completely eaten down that the sheep of the neighbourhood are for a time half-starved. The sheep know as well as the shepherds when the procession has arrived at the end of its journey. In April their migratory instinct renders them restless, and, if not guided, they set forth unattended to the cooler hills. In spite of the vigilance of the shepherds, great numbers often escape; if not destroyed by the wolves, there is no danger of losing these stragglers, for they are found in their old pasture, quietly awaiting the arrival of their companions."

The chief countries which supply us with sheep and lambs' wool are Russia, Hanse Towns, Argentine Confederation, British Possessions, Africa, British India, and Australia.

There are other ruminant animals from which the wools of commerce are obtained besides the sheep. The following are the chief of these :—

Angora Goat (*Capra Angorensis*, Hasselquist).—This animal inhabits the mountains in the vicinity of Angora, in Asia Minor. In colour it is milk white; legs short and black, horns spirally twisted and spreading; the hair on the whole body is disposed in long, pendulous, spiral ringlets, and is highly valued in Turkey, the finest and most costly Turkish robes being manufactured from the fleece, which is as soft and fine as silk. It was first brought into the markets of Europe under the name of mohair. Its exportation, unless in the shape of yarn, was formerly prohibited, but it is now allowed to be exported unspun.

Mohair is transmitted to England principally from Smyrna

and Constantinople. It is manufactured into fine shawls, camlets, velveteens, plushes, braidings, decorative laces, and trimmings for gentlemen's coats. The manufacture is principally carried on at Bradford and Norwich. In 1864, 4,737,330 lb. of mohair, valued at £650,191, were imported into the United Kingdom.

Thibet Goat (*Capra hircus*).—The costly and beautiful Cashmere shawls are made from the delicate downy wool found about the roots of the hair of this animal, which inhabits the high table-lands of Thibet, where these shawls are manufactured. These Oriental fabrics are woven by very slow processes, and are therefore very expensive, being sold in Paris at from 4,000 to 10,000 francs a-piece, and in London at from £100 to £400. "The wool is spun by women, and afterwards coloured. A fine shawl, with a pattern all over it, takes nearly a year in making. The persons employed sit on a bench at the frame—sometimes four people at each; but if the shawl is a plain one, only two. The borders are worked with wooden needles, there being a separate needle for each colour, and the rough part of the shawl is uppermost whilst it is in progress of manufacture." To the people of Cashmere this manufacture is very important; about 16,000 looms are continually at work, each one giving employment to three men. The annual sale there is calculated at 30,000 shawls.

It has long been the aim of European nations, on account of the beauty and value of these shawls, to imitate them, if possible, and apply to their manufacture the more speedy and elaborate methods which modern science has placed within our reach. The French have been most successful, and shawls are now produced at Paris, Lyons, and Nismes, known in commerce as French cashmere, which closely approximate in stuff and style of work to the Oriental, while much lower in price, although still costly. Norwich, Bristol, Paisley, and Edinburgh have also manufactured very good imitations of these shawls. The Cashmere wool imported for this purpose comes into Europe through Kasan, on the eastern bank of the Volga, and also directly from India and Persia.

The quantity of goats' hair or wool imported in 1867 was 2,648,360 lb.; the imports of the same material manufactured were of the value of £127,093.

Alpaca (*Llama Pacos*, Gray).—The llamas may be regarded as the camels of South America, to which tribe of animals they belong. They inhabit the slopes of the Peruvian Andes, and the mountains of Chili, keeping together in herds of from 100 to 200, and never drinking when they have a sufficiency of green herbage. The alpaca is about the size of a full-grown deer, and very graceful in appearance. Its fleece is superior to that of the sheep in length and softness, spins easily, and yields an even, strong, and true thread. Pizarro found this animal used as a beast of burden, and its wool employed for clothing by the natives of that country.

Alpaca wool arrives in this country in small bales, called ballots, weighing about 70 lb., and generally in a very dirty state. It is sorted into eight different varieties, each fitted for a particular class of goods, and then washed and combed by machinery. The principal articles manufactured from it consist of alpaca lustres, fancy alpacas, and alpaca mixtures. Nearly all the alpaca wool imported into England is worked up in the Bradford district. In 1863 our imports from Peru were 2,772,836 lb.; from New Granada, 622,889 lb.; and from other places in South America, 6,857 lb.

The *Llama vicuña* and *L. guanaco*, other species of these animals inhabiting the same regions, yield fine hair, but at present of little commercial value.

In 1867 we imported 233,703,184 lb. of wool (sheep, lamb, and alpaca) from Europe, South America, South Africa, the East Indies, and Australia. Our exports of wool in 1867, to foreign countries and our colonial possessions, amounted to 90,832,584 lb.

The best wool is grown in Germany, which annually produces 67,200,000 lb. The finest kind passes in commerce under the name of "electoral wool." Next to Germany, Australia ranks in importance as a wool-growing country; the merino breed of sheep has been introduced there with unexampled success. In 1807 the first importation of Australian merino wool was received in England, amounting to only 245 lb. It has now grown to national importance, amounting in 1852 to 36,000,000 lb., valued at £2,000,000 sterling. Probably a more extensive and instructive collection of wools was never brought together than that contributed to the Great Exhibition of 1851, in this country; showing, in a remarkable manner, the extent to which wool-bearing ruminants have been fostered by man, their wide geographical diffusion, and the influence of climate in modifying the characters of their fleeces. Samples of wool were there for inspection and comparison, from Chinese Tartary, Thibet, and India in the East, to the lately redeemed tracts of the United States in the far West; and from Iceland and Scandinavia to the Cape of Good Hope and Australia.

Although Europe now surpasses Oriental nations in the artistic working of cotton and silk, yet the same cannot be said of the manufacture of shawls and carpets; for, besides the Cashmere shawls made at Kashmir, in the kingdom of Lahore in Thibet, and also at Delhi in British India, carpets of peculiar and unequalled beauty still come exclusively from Persia and the Levant.

VI.—LEATHER.

Leather is an animal's skin chemically changed by the process called tanning. The skin is prevented from putrefying, and rendered comparatively impervious to water, by the vegetable astringent, tannin, found in the bark, fruit, and leaves of various plants; this uniting with the gelatine of the skin, forms a tannate of gelatine. The skin, thus changed, was called by our Saxon ancestors "lith," "lithe," or "lither"—that is, soft or yielding, whence our term "leather."

The skins are first cleansed from hair and cuticle, by being soaked for several days in a pit of lime water; this loosens the hair and cuticle, so that it is easily scraped off with a curved knife, upon a half cylinder of wood, called a beam. The hair thus removed is sold to plasterers, who use it in their mortar. The skins are now steeped for a few days in a sour liquor of fermented rye or barley, or in weak sulphuric acid. By this process, called "the raising," the pores are distended and rendered more susceptible of the action of the tan. The skins are then put into the tan-pit, in alternate layers, with crushed oak bark, valonia, catechu, dividivi, and other vegetable astringents, and the pit is filled with water. As the tannin is taken up by the skins, it becomes necessary to empty the tan-pit, and add fresh supplies of tanning material and water. The time required to tan the skins, or transform them to leather, depends on their thickness and other circumstances, and varies from four months to two years. When fully tanned, the leather, if cut through, is of a uniform brown colour—anything like a white streak in the centre showing incompleteness in the process. It is now stretched upon a convex piece of wood called a "horse," beaten and smoothed, or passed between cylinders to make it more solid and supple, and lastly, dried by suspension in an airy covered building.

Tanned leather often undergoes the further operation of currying, or impregnation with oil. Leather, prepared as already described, when it is received by the currier is by him rendered smooth, shining, and pliable, so as to make it suitable for the purposes of the shoemaker, coachmaker, saddler, and harness-maker. First, it is soaked in water to render it pliable, then stretched upon the beam and shaved smooth with a knife, next rubbed with a polishing stone, and while still wet besmeared with a mixture of fish-oil and tallow, and hung up in a loft to dry. As it dries, the water only evaporates, the oil penetrating the pores of the leather. The grain, or hair side, is then blackened with copperas water, or sulphate of iron in solution, the iron uniting with the gallic acid of the tan, and producing an inky dye, or a gallate of iron. Leather so prepared is chiefly used for the uppers of ladies' shoes. Leather for the uppers of men's boots and shoes is blackened on the flesh side, or waxed, as it is termed, with lampblack and oil, which is rubbed in with a hard brush. The thick leather for the soles of boots and shoes is simply tanned without being curried.

But leather can be made without tannic acid. Skins may be preserved by means of alum and salt, and leather so made is called in the trade "tawed leather," and is quite as durable and much softer. Gloves are usually made from tawed leather. Skins intended to be tawed pass through a series of preliminary operations, resembling those by which skins are made ready for tanning (the use of ordures is, however, indispensable). They are then immersed in a solution of alum and salt, to which, for the superior kinds of leather, flour and yolk of eggs are added. They are next dried in a loft, smoothed with a warm iron, and

then softened on a stake, when they are dyed of various colours for gloves and ladies' boots. The French are skilled in this art. At Annonay, a town about fifty miles from Lyons, tawing operations are carried on so largely, that 4,000,000 kid-skins are dressed there annually. It has been computed that France and England consume 6,000,000 eggs yearly in preparing kid leather. These eggs are kept in lime-water by the leather dresser, to preserve them until they are wanted. The average quantity of leather gloves annually made in the United Kingdom has been estimated at 12,000,000 pairs. We import also largely from France. In 1867, 10,893,780 pairs were received from that country. The imports of tanned and untanned hides in 1867 were 975,168 cwt.

The leathers known in commerce as *chamois* and *buff leather* are prepared much in the same way as tanned and tawed leather, only that oil is substituted for the alum and tannic acid. The skin of the chamois is not always used; more frequently sheep and doe skin. Wash leather is an example of this kind of preparation.

Russia leather, the smell of which is so agreeable, is prepared in the usual way, then tanned with the bark of the willows (*Salix cinerea* and *Salix caprœa*), and afterwards curried with the empyreumatic oil from the bark of the birch tree, which imparts to it its peculiar odour. M. Chevreul, who investigated the chemical nature of this odoriferous substance, called it *betuline*.

Morocco leather of the finer qualities is made from goat-skins tanned with sumach, and inferior morocco, or roan, from sheep-skins. The hair, wool, and grease are removed as usual, and the skin, thoroughly cleansed, is reduced to the state of simple membrane, called pelt. Each skin is then sewn by its edges into the form of a bag, the grain, or hair side, being outwards. A strong solution of sumach having been put into the bag, it is distended with air like a blown bladder, and the aperture tied up. About fifty of these skins, so distended, are thrown into a tub containing a warm solution of sumach—the tanning liquor—in which they are allowed to float. In a few hours they are tanned, removed from the bath, the sewing is then undone, and they are scraped and hung up in the drying loft. Red morocco leather derives its colour from cochineal, which, boiled in water with a little alum, forms a red liquor, in which the skins are immersed before being put into the sumach bath. In the case of black morocco, the skins are sumached without any previous dyeing, and the black colour is given by applying with a brush, to the grain side, a solution of red acetate of iron; blue is communicated by indigo; puce colour by logwood, with a little alum; green is derived from Saxon blue, followed by a yellow dye made from the chopped roots of the barberry; and for olive, the skins are first immersed in a weak solution of green vitriol, and then in a decoction of barberry root, containing a little Saxon blue.

The thickest and most substantial leather now in general use is that made from the hides of the wild horses found throughout the pampas in South America. It is employed for the soles of boots and shoes, harness, saddlery, leather trunks, hose for fire-engines, pump-valves, military gloves and belts. Deer-skins are used for the finer kinds of morocco leather, and for bookbinding. Calf-skins, tawed, are used by bookbinders; tanned and curried, by boot and shoemakers. Sheep-skins, simply tanned, are employed for inferior bookbinding, for leathering bellows, and other purposes where a cheap leather is required. Morocco leather is used for coach linings, for covering chairs and sofas, bookbinding, pocket-books, etc. A thin leather, called *skiver*, is used for hat linings. There is an immense demand for thin leathers, and machinery for this purpose is now constructed with such accuracy that it will split a sheep-skin into three parts. The grain side of the skin is then used for skiver, the middle for vellum and parchment, and the flesh side is transferred to the glue maker. On parchment we inscribe our deeds, and on vellum all our State documents.

The leather manufacture of Great Britain is of great importance, and ranks next in value and extent to those of cotton, wool, and iron. The census of 1851 showed that 350,000 persons were engaged in the different branches of the leather manufacture, and its entire annual value has been computed at more than £20,000,000 sterling, the leather for boots and shoes alone being valued at £12,000,000. Most of the leather made in the kingdom, and the articles manufactured from it, are used at home. Our exports are, however, considerable, and in 1867 were as follows:—

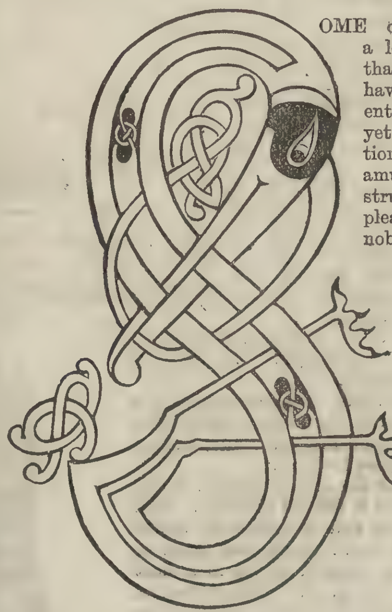
		Value.
Tanned unwrought	43,584 cwt.	£428,268
Boots and shoes	3,284,883 pairs.	950,794
Saddlery and harness	——	220,475
Wrought leather of other sorts .	1,176,146 lb.	258,541

The Australian colonies are the great purchasers of these goods.

PRINCIPLES OF DESIGN.—IV.

By Christopher Dresser, Ph.D., F.L.S, etc.

EMPLOYMENT OF THE GROTESQUE IN ORNAMENT.



OME other principles of a less noble character than those which we have already noticed as entering into ornament yet remain to be mentioned. Man will be amused as well as instructed; he must be pleased as well as ennobled by what he sees. I hold it is a first principle that ornamentation, as a true fine art, can administer to man in all his varying moods, and under all phases of feeling. Decoration, if properly understood, would at once be seen to be a high art in the truest sense of the word, as it can teach, elevate, refine, induce lofty aspirations, and allay sorrows; but we have now to notice it as a fine art, administering to man in his various moods, rather than as the handmaid to religion or morals.

Humour seems to be as much an attribute of our nature as love, and, like it, varies in intensity with different individuals. There are few in whom there is not an amount of humour, and in some this one quality predominates over all others. It not unfrequently happens that men who are great thinkers are also great humorists—great talent and great humour being often combined in the one individual.

The feeling for humour is ministered to in ornament by the grotesque, and the grotesque occurs as the work of almost all ages and all peoples. The ancient Egyptians employed it, so did the Assyrians, the Greeks, and the Romans; but none of these nations used it to the extent of the artists of the Celtic, Byzantine, and the "Gothic" periods. Hideous "evil spirits" occurred on the outside of almost every sacred Christian edifice at one time, and much of the Celtic ornament produced by the early monks consisted of an anastomosis, or network of often grotesque creatures.

The old Irish crosses were enriched with this kind of ornamentation,* and some of these decorative embellishments are of extraordinary interest; but those who have access to the beautiful work of Professor Westwood on Celtic manuscripts will there see this grotesque form of ornament to perfection. As regards the Eastern nations, while nearly all have employed the grotesque as an element of decorative art, the Chinese and Japanese have employed it most largely, and for it they manifest a most decided partiality. The drawings of dragons, celestial lions (always spotted), mythical birds, beasts, fishes, insects,

* Casts of one or two of these can be seen in the central transept of the Crystal Palace at Sydenham.

and other supposed inhabitants of the Elysian plains which these peoples produce, are most interesting and extraordinary.

Without in any way going into a history of the grotesque, let us look at the characteristic forms which it has assumed, and what is necessary to its successful production. We have said that the grotesque in ornament is the analogue of humour in literature. This is the case; but the grotesque may represent the truly horrible or repellant, and be simply repulsive. This form is so seldom required in ornamentation that I shall not dwell upon it, and when required it should always be associated with power; for if the horrible is feeble it cannot be corrective, but only revolting, like a miserable deformed animal.

Fig. 12.

I think that it may be taken as a principle, that the further the grotesque is removed from an imitation of a natural object the better it is, provided that it be energetic and vigorous—lifelike. Nothing is worse than a feeble joke, unless it be a feeble grotesque. The amusing must appear to be earnest.

In conjunction with this chapter we engrave a series of grotesques, with the view of illustrating my meaning, and I would fain give more, but my space will not permit me to do so.

The initial letter at the commencement of this lesson is a Celtic letter S, formed of a bird. It is quaint and interesting, and is sufficiently unlike a living creature to avoid giving any sense of pain to the beholder, while it is yet in a most unnatural position. It is, in truth, rather an ornament than a copy of a bird, yet it is so suggestive as to call forth the thought of one of the "feathered tribe." It should be noticed, in connection wth this figure, that the interstices between certain portions of the creature are filled by a knot. This is well—the whole thing being an ornament, and not a naturalistic representation.

Fig. 11.

Fig. 11 is a Siamese grotesque head, and a fine sample it is of the curious form of ornament which it represents. Mark, it is in no way a copy of a human head, but is a true ornament, with its parts so arranged as to call up the idea of a face, and nothing more. Notice the volutes forming the chin; the grotesque, yet highly ornamental, lines forming the mouth and the upper boundary of the forehead, and the flambeauant ears: the whole thing is worthy of the most careful study.

Fig. 12 is a Gothic foliated face; but here we have features which are much too naturalistic. We have, indeed, only a hideous human face with a marginal excrescence of leafage. This is a type to be avoided; it is not droll, nor quaint; but is simply unpleasant to look upon.

Fig. 13 is a fish, with the feeling of the grotesques of the Middle Ages; it is modified from one in Colling's "Art Foliage." It is a good type, being truly ornamental, and yet sufficiently suggestive.

In order that I may convey to the reader a fuller idea of my views respecting the grotesque than I otherwise could, I have sketched one or two original illustrations—Fig. 14 being suggestive of a face, Fig. 15 of a skeleton (old bogey), and Fig. 16 of an impossible animal. They are intentionally far from imitative. If naturalistic some would awaken a sense of pain, as they are contorted into curious positions, whereas that which induces no thought of life or feeling induces no sense of pain.

Of all grotesques with which I am acquainted, the dragons of the Chinese and Japanese are those which represent a combination of power, vigour, energy, and passion most fully. This is to be accounted for by the fact that these peoples are believers in dragons. When the sun or moon is eclipsed they believe that the luminous orb has been swallowed by some fierce monster which they give form to in the dragon, and upon the occurrence of such a phenomenon they come with cans and kettles to make rough music, and thus cause the monster to disgorge the luminary, the brilliancy of which it would otherwise have for ever extinguished. I can imagine a believer in dragons drawing these monsters with the power and spirit that the Chinese and Japanese do; but I can scarcely fancy that a disbeliever could do so—a man's very nature must be saturated with a belief in their existence and mischievous power, in order that he may embody in his delineation such expressions of the assumed character of this imaginary creature as do the Chinese and Japanese.*

Although I am not now considering the structure of objects, I may say that the grotesque should frequently be used where we meet with naturalistic imitations. We not unfrequently see a figure, naturally imitated, placed as a support to a superincumbent weight—a female figure as an architectural pillar bearing the weight of the entablature above, men crouched into the most painful positions supporting the bowl of some colossal fountain. Naturalistic figures in such positions are simply revolting, however perfect as works of sculpture. If weight has to be supported by that which has a resemblance to a living creature of any kind, the semblance should only be suggested; and the more unreal and woodeny (if I may make such a word) the support, if possessing the quaintness and humour of a true grotesque, the better.

It is not the business of the ornamentist to produce that which shall induce the feeling of continued pain, unless there is some exceptional reason for his so doing, and such a reason is of rare occurrence.

* I have met with many fine Japanese and Chinese grotesques at the warehouse of Mr. Goode, of 32, King William Street, City, whose taste in importing these things is great.

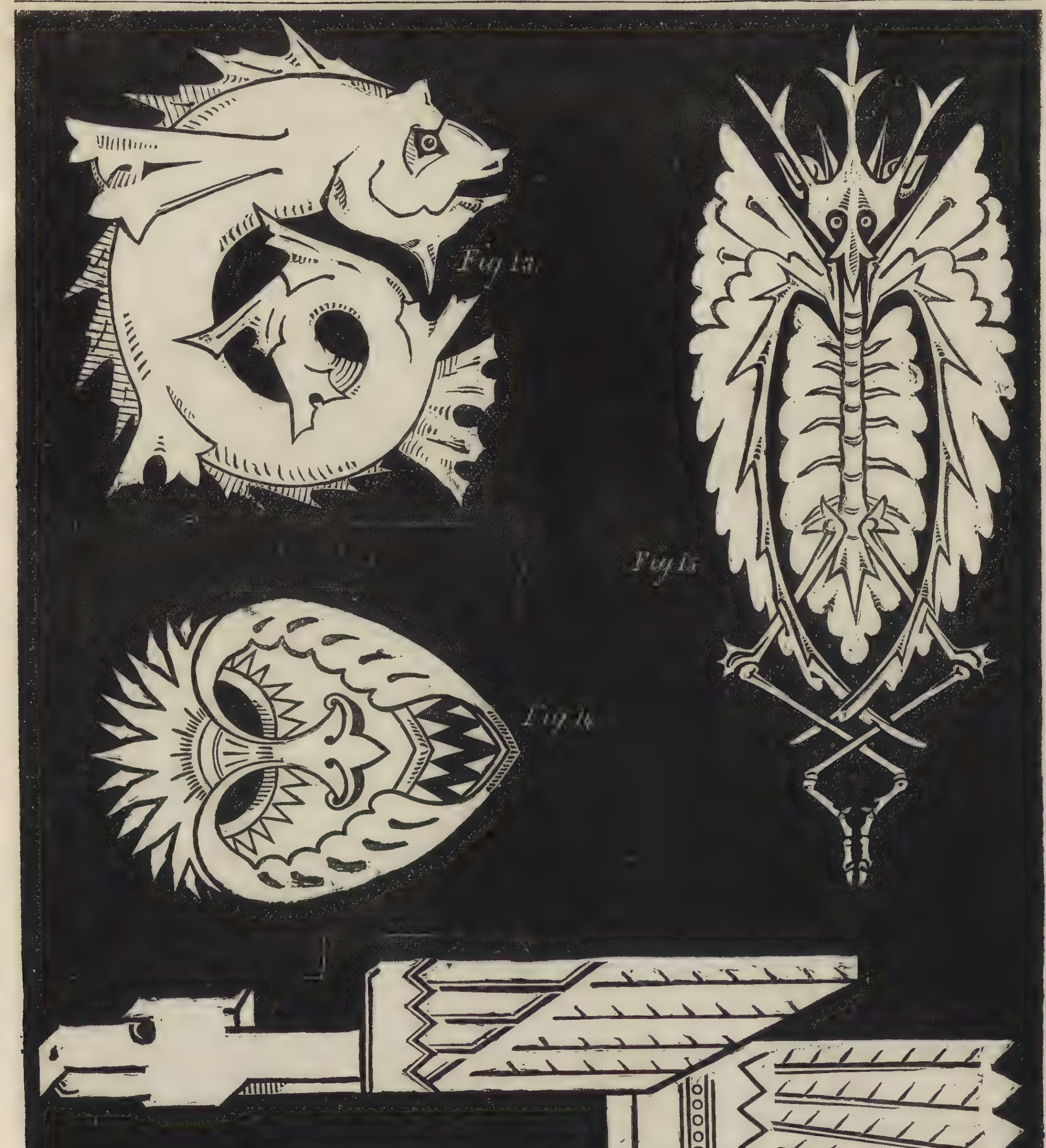


Fig 13.
Fig 15
Fig 14
Fig 16.

WEAPONS OF WAR.—III.

BY AN OFFICER OF THE ROYAL ARTILLERY.

GUNPOWDER.

THE powder used for the charges of small arms necessarily influences in a great degree the efficiency of the weapons. There is no direction in which English artillerymen have laboured so determinedly, and, on the whole, successfully, as in the direction of the improvement of the powder for guns and small arms. For the moment we are engaged with small arms only; but it will, perhaps, be convenient if we deal with the subject of powder as a whole, and take this occasion to speak generally of the different descriptions of gunpowder in use in the British service.

Gunpowder, as all the world knows, is an intimate mixture of saltpetre, sulphur, and charcoal.

The proportions of the ingredients differ in various countries. The following table, extracted from Captain Goodenough's "Notes on Gunpowder, Prepared for the Use of the Gentlemen Cadets," shows the rates, or per-centage, of the several ingredients in the powder of different countries:—

	Saltpetre.	Sulphur.	Charcoal.
England (Government powder)	75	10	15
France, Prussia, United States	75	12·5	12·5
Russia	73·78	12·63	13·59
Austria	76	12·5	11·5
Spain	76·47	12·75	10·78
Sweden	75	16	9
China	76	14·4	9·6
Switzerland	76	14	10

English powder has long held almost undisputed supremacy as to excellence of quality and strength. The purity of the ingredients employed, and the elaborate care which is bestowed upon all the processes of manufacture, result in the production of an explosive and propellant agent of great power. Indeed, the chief objection to the English powder has been that it is too strong. We believe that we may safely affirm that there is no powder in the world equal to that which is produced at the Government mills at Waltham Abbey, unless it be the powder which is turned out from the mills of some of the leading English makers, such as Curtis and Harvey, Hall and Sons, and others.

The action of gunpowder is due to the almost instantaneous decomposition of the saltpetre by the charcoal, the latter being burned by the oxygen of the saltpetre, with which it combines in the act of burning to form carbonic acid gas. At the same time the oxygen in the saltpetre becomes separated from the nitrogen with which it was combined.

The explosive force of gunpowder is mainly due to the sudden evolution at a high temperature of these two gases—carbonic acid and nitrogen. In this action, it will be observed, the sulphur plays apparently no part. Indeed, it is a fact that gunpowder may be made without sulphur at all; but the explosive force of a mixture of saltpetre and charcoal is comparatively feeble, because the evolution of the gases in such a mixture is very slow, and the temperature of the gases, and the consequent expansion, relatively small. Sulphur, therefore, which ignites at a much lower temperature than either of the other two ingredients, is added to render the action more rapid, and, by raising the temperature of the gases, to increase their expansive power. Sulphur also increases the volume of the gas, by combining with the potassium in the saltpetre, and so liberating the oxygen with which that potassium was combined, the liberated oxygen becoming available for the burning of the charcoal.

It is to the presence of the sulphur that we owe the white smoke and the solid residue of fired gunpowder. The smoke and residue are chiefly sulphate of potassa (K_2SO_4) and carbonate of potassa (K_2CO_3), resulting from the combination of the sulphur with the potassium. Some of the sulphide of potassium is carried out by the escaping gases, when it catches fire and burns—forming flash and smoke; that portion of it which is not carried out being left in the form of a solid residue.

The explosion of a charge of gunpowder can be effected by raising a single grain of the powder to a temperature of about 600°, which is about the temperature at which the sulphur sublimes. When one grain is ignited, the resulting gases are transmitted by their own expansive power through the interstices, igniting other grains, and finally consuming the whole charge. From this it follows that the ignition of a charge of gunpowder is not necessarily—indeed, it is not under any circumstances—really instantaneous. Gunpowder, in fact, burns, but the combustion generally takes place at so great a rate that it practically amounts to instantaneous ignition. This consideration brings us to a very important branch of our subject.

Those who have followed us thus far will have recognised that the explosive force of gunpowder is not determined alone by the amount of gas developed. It depends upon three main causes: the amount of gas developed; the heat evolved, by which the expansion of the gases is influenced; and the rapidity with which the gases are produced. As to the first two points, we have said all that is necessary for the purposes of the present paper. As to the third point, it is clear that if the rapidity of the inflammation of the charge depend, *cæteris paribus*, upon the rapidity with which each grain successively becomes ignited and consumed, it is possible largely to influence the action of the powder by altering the size and shape of the grains.

Thus, for example, to put an extreme case:—If the powder were not disposed in grains at all, but existed in the form of a solid mass, like what is technically known as "press cake," the inflammation of the mass would be very slow indeed; the flame applied to one portion would flash over the whole surface, and then proceed to consume the mass from outside to within, burning it slowly away in successive layers. If the mass, however, be broken up into an infinite number of small particles, the effect is to open a large number of passages through which the gases at once rush, thus practically igniting each grain in the same instant of time; and in proportion as the individual grains are of a size and shape which permit of their being readily consumed, so will the burning of the whole mass of powder, and consequently its conversion into gases, be rapidly effected.

Here we have the two extremes—of slow and rapid ignition; extremes which are susceptible of modification at will, and between which lie the various applications which the artillerist makes use of. In short, it comes to this, that the action of gunpowder can be largely influenced by mechanical means, and without prejudice to its chemical character. Of course, the chemical character can be influenced by a change in the proportion of the ingredients, in their purity, in their mode of manufacture, etc.; but obviously the better course is first to discover, by theory and practice, the best chemical constitution for gunpowder—that constitution which is capable of producing the maximum results from the three ingredients of which gunpowder is composed—and then to seek mechanically to control the violence or rapidity of the action. In practice, this is what we do in England, and the field of experimental inquiry thus opened out is exceedingly wide.

One interesting application of this theory is that which was proposed by Mr. Gale, the well-known experimentist, of Plymouth. Mr. Gale, following—although perhaps unconsciously—the steps of the French artillerist, Piobert, and those of the Russian chemist, Fadéieff, filled up the interstices of gunpowder with an inexplosive substance, such as finely-powdered glass, and in this way, by cutting off communication between one grain and another, made the powder absolutely inexplosive. Mr. Gale proposed to dilute all powder in store with the ground-glass, and when required for use to sift out the glass, when the powder would resume its natural explosiveness. The idea was ingenious, but it was open to many practical objections, which, in spite of the success that, on the whole, attended the long series of costly experiments which were made, ultimately determined the rejection of the proposition, although at first sight it had appeared to be feasible enough.

More useful advantage is taken of the fact that the explosive violence of gunpowder can be readily controlled by mechanical means, in connection with the adoption, for the different natures of fire-arms, of the powder most suited to them. The size of the charge, the nature of the work required to be done, and the reduction of the strain upon the weapon, are the three considerations which mainly influence the determination of the most suitable

powder. A few words upon each of these points in succession may be useful.

1. *The size of the charge.*—It might be hastily assumed that the size of the charge could not have much influence upon the nature of the combustion, and therefore could not affect the selection of the powder for particular arms. The popular notion would probably be—that if a powder, of a particular size and form of grain and density, burn quicker than another powder in *any* fire-arm, it must burn quicker in *all* arms. And this argument would probably go forward to the conclusion that fine-grain powder must, under all circumstances, burn quicker than large grain. Both these opinions would be erroneous. The rapidity of action of gunpowder depends upon (*a*) the rate of burning of each grain, called the "velocity of combustion;" and (*b*) the rate at which the grains successively become ignited, called the "velocity of ignition." In the case of an open train of powder, the velocity of ignition is independent of the interstices between the grains—the flash travels over and along the train, not through it. So also with small enclosed charges. When the distance which the flame has to traverse is inconsiderable, the velocity of ignition is an element of subordinate importance to the velocity of combustion. In the case of very large charges, however, it is otherwise: the velocity of ignition then becomes a more important element. Consequently, according to the size of the charge, those elements which favour velocity of ignition will have a varying importance, and thus it is impossible to predicate from the size and shape of the grain —which are the elements that mainly influence the velocity of ignition—whether a certain powder will be quick or slow. Other conditions being the same, a fine-grain powder will generally burn quicker than a large grain, except in very large charges, where a very fine-grain powder will not burn so quickly as the same powder disposed in larger pieces.

2. *The nature of the work to be done* bears, of course, directly upon the selection of powder. Thus, in a smooth-bore musket the chief point is rapidity of action; while, with rifled small arms, regularity of combustion and uniformity of action are of greater importance. Indeed, a very quick powder is unsuited for rifled small arms. In the case of an expanding bullet, such as is used in the Enfield rifle, and which was described in our last paper, it is desirable to make the pressure upon the plug as little of a blow as possible; hence a comparatively slow action is preferred. And in the case of arms firing non-expanding bullets, such as the Martini-Henry—which will presently be described—too rapid a powder, by escaping over the bullet, tends to cause fouling. Therefore, we find that the powder which was used for the old smooth-bore arms, and which was known as "fine grain," was of a size to be retained upon a sieve of 36 meshes to the inch, and to pass through one of 16 meshes. The powder used for the Enfield rifle is of a size to be retained upon a sieve of 20 meshes to the inch, and to pass through one of 12 meshes. The powder for the Enfield rifle is, however, different from the old smooth-bore powder in other respects than size of grain. It is made with dogwood instead of alder charcoal, the ingredients are more thoroughly incorporated, the density is rather less, and the grains are more rounded, more uniform in form, and more highly glazed. Again, as an example of the adaptation of powder to the work to be done, may be instanced the use of an exceedingly quick powder for the bursting charges of Shrapnel shell, where the powder is required to effect the rupture of the shell and the release of the bullets as instantaneously as possible, so as to diminish the possibility of the charge acting upon the balls. Finally, in the case of all rifled guns, it is necessary to select as uniform a powder as possible, and for rifled guns a special powder has generally been employed.

3. *The reduction of the strain upon the weapon.*—When we have to deal with large guns, we are met by the third consideration which we have named, viz., the importance of reducing the strain upon the gun as much as possible. In the use of small arms this consideration may be ignored. The strength of the barrel is largely in excess of what is requisite to resist the explosion of the regulated charge of gunpowder, however rapid in its action; and the same holds good with regard to field-guns and guns of moderate calibre. But it is far different when passing from weapons which fire only 70 or 80 grains of powder, or guns which fire only a few pounds, we get among the weapons which consume 40, 60, and 100 pounds of powder at each discharge. The great 35-ton guns built at Woolwich fire 120 pounds of powder—that is, about a barrel and a quarter each. With such charges as these it is necessary to modify the action as much as possible; it is desirable at the same time to do this without diminishing the power of the gun by any reduction in the strength of the powder. This is a problem which has each year become of increasing importance, as the guns and charges have become larger and the strain more severe. It is a problem which accordingly has actively occupied the attention of artillerists for the last few years. The strain which the gun suffers from most is the violent initial strain at the moment of the first ignition of the charge. If the development of gas be intensely sudden, we have a violent local effect, an expression of irresistible force upon the sides and end of the bore before the shot is moved. A familiar experiment illustrates this. If a charge of powder be placed in a thin glass tube, and a charge of fulminating mercury—which, compared with gunpowder, is intensely sudden and violent in its action—be placed in another; and if the two tubes be closed with a cork, and their respective charges exploded, the cork will be blown out of the tube which contains the gunpowder, while the tube which contains the fulminate will be shattered to pieces. What we require in a gun is, not to burst it, but to blow out the shot. It is desirable, therefore, with very heavy charges to modify the action of the powder, and this without altering its chemical character and strength. Accordingly, the size and shape of the grains, their density, and the degree of glazing imparted to them—physical conditions which all affect the rate of explosion—are modified in such a way as to make the explosion less rapid, and to distribute the pressure more evenly through the bore.

With this view the Russians, Prussians, and others employ what is called "prismatic powder"—powder which is compressed into hexagonal prisms, perforated to allow of the passage of the gases. This powder is, no doubt, a great improvement upon the granulated powders; but in England it has been found inferior to both "pellet" and "pebble" powders. "Pellet" powder was adopted provisionally in 1866 for use in very heavy charges. It consists of cylindrical pellets instead of grains—the diameter of the pellets being three-fourths of an inch, and their thickness about half an inch. Latterly, a special committee, which is still sitting, has recommended the adoption of a powder, which, from its representing in form and dimensions large pebbles of the size of the top of a man's thumb, has received the name of "pebble" powder. This powder has lately been adopted for use with the heavier rifled guns. Not merely does the use of this powder greatly decrease the local strain upon the breech end of the gun, being far more gradual in ignition; but it is capable of imparting, with a reduced strain, a far higher velocity to the projectile. Thus, not only is the power of our guns greatly increased, but their time of service is prolonged in proportion to the less strain imposed upon them. The uniformity of action of this powder is also greater than that of the ordinary, old-fashioned cannon powder.

The maximum pressure exerted upon an 8-inch gun with 35 pounds of pebble powder is estimated at 15·4 tons per inch, as against 29·8 tons exerted by the former cannon powder ("rifle large grain"), and the initial velocity of the projectile has been increased from 1,363 to 1,410 feet per second. These are important results to have achieved, and we hope, before this series of papers is concluded, to say something of the instruments and means by which this powder question has been worked.

It appears, then, that while the chemical constitution of all English powder is the same, the physical characteristics of different powder differ widely, the size of grain ranging from the fine "pistol" powder, of which the grains are retained upon a sieve of 72 meshes to the inch and pass through one of 44, up to the leviathan "pebble" powder, of which the lumps (for they are hardly to be called grains) are retained between sieves of $\frac{5}{8}$ and $\frac{3}{8}$ inch meshes respectively. There is no more important subject to the artillerist and the rifleman than that of powder. It has been appropriately called "the soul of artillery." So comprehensive and difficult a subject cannot be exhaustively discussed in a single article, and the foregoing remarks make no pretensions to an exhaustive character. They merely furnish a slight sketch of the more marked features of a very great and interesting subject.

TECHNICAL DRAWING.—X.

DRAWING FOR CARPENTERS: ROOFS.

THE whole subject of roofs being very fully treated of in the lessons on "Building Construction," it will not be necessary in this course to give many examples of them.

The following examples are illustrations of roofs in which iron is combined with wood, by which means far greater lightness is attained than when wood only is employed. In Fig. 70 A A and B B are tension-rods; by screwing up the nuts at the ends of these, the straining-pieces, D D, are forced upward, and being perpendicular to the principals, they give support to them at their middle points. When these tension-rods are tightened, it will be seen that the tie-rod, C, is also strained, and perfect stiffness is thus attained.

Fig. 71 shows the manner in which the principals meet. The apex is covered by an iron plate; this is bent downward so as to form a base for the support of the ridge-timber; a plate extends below the shoe for the attachment of the tension-rods.

Fig. 76 is a similar subject, with an extra breadth of plate, and a third hole into which the end of a vertical tension-rod, which acts as a king-post, is bolted.

Fig. 77 shows the cast-iron shoe for the reception of the lower ends of the principals.

Fig. 78 is a truss used in a railway-shed in Paris, designed by M. Armand. This is an application of Emys' system of building up the arch-beam of plates of timber, and to this is added a wrought-iron tie-rod, by which the ends are confined; this is tightened up by the tension-rod, A B, in the middle.

Figs. 79 and 80 are the elevation and plan of the junction at B, showing the means by which the tie-rod is tightened up. Fig. 81 shows another arrangement for attaching and tightening a tension-rod.

In drawing these examples, the student cannot do better than follow the construction as described, and draw the various

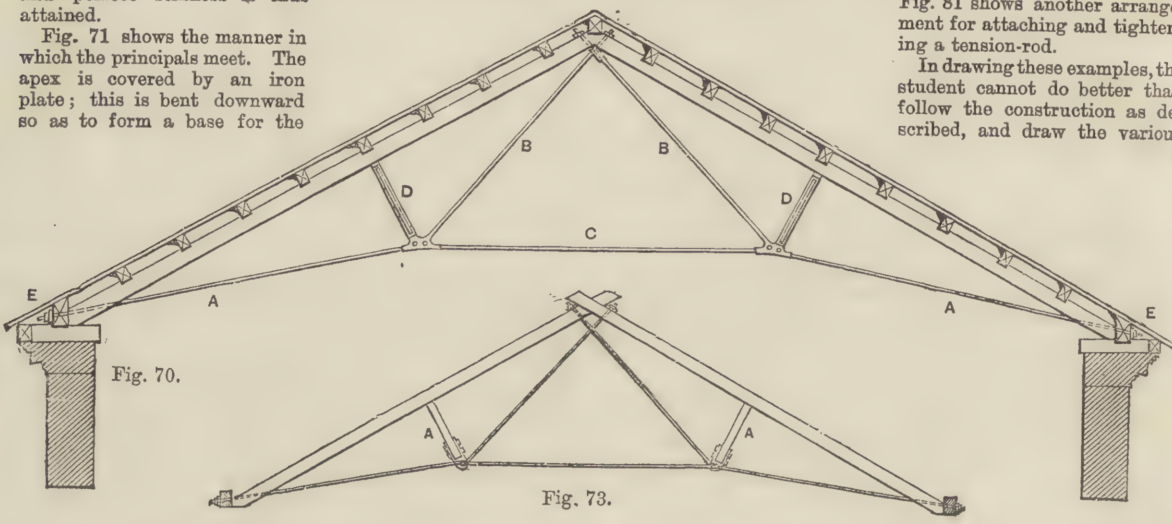


Fig. 70.

Fig. 73.

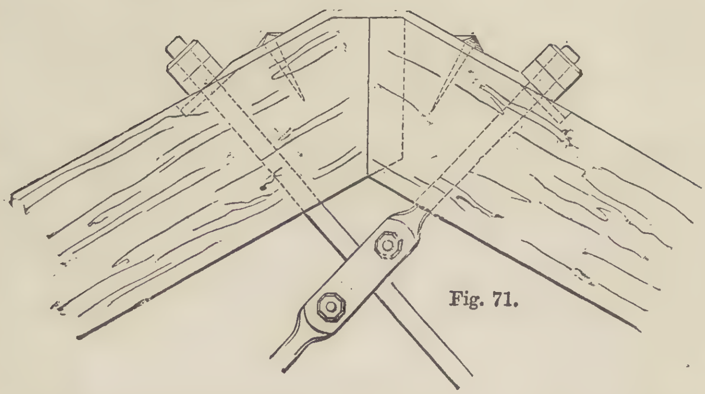


Fig. 71.

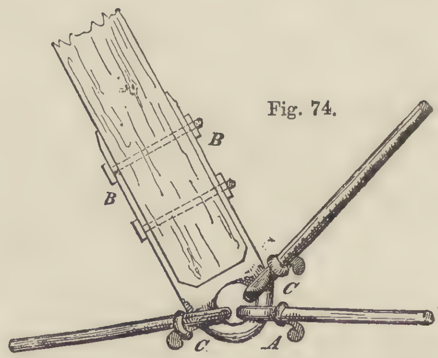


Fig. 74.

nuts, which shall be at right angles to the tension-rods. The nuts are double in order to cause them to act upon a greater length of the rod than would be the case if single ones were employed.

Fig. 72 illustrates the manner in which the nuts act at the lower ends of the principals, a cast-iron boss being attached to the wood-work, with one face slanting, so that in this case also the faces of the nuts may be at right angles to the tension-rods.

Fig. 73 is a roof-truss on precisely the same principle as the other, the difference being merely that the straining-pieces, A A, are of wood instead of cast iron; at their lower end, however, they are fitted with a wrought-iron shoe (Fig. 74, B B), into the ringed end of which the tension-rods hook. These hooks are confined by rings, and their ends are then bent round as shown at C C and A.

Fig. 75 is a section of a cast-iron double shoe, or housing, for the reception of the upper ends of the principals, and also for members in the order in which they would be employed in the construction. He will, by this mode of proceeding, learn to *make* a drawing in an intelligent manner, instead of merely *copying* the lines. It is advisable that the drawing should be made of at least twice the size of the original, and if neatly inked and nicely coloured it will become an important addition to the portfolio. This affords an opportunity of advising each student to provide himself with a portfolio, and to keep his drawings *flat*. When drawings are rolled one over another, they are put away in a drawer or cupboard (if indeed they are so taken care of); those which were drawn first are buried in the depths of the roll, are seldom seen, and are often entirely forgotten; even if taken out for reference, they will not keep flat, but are wrinkled and difficult to measure from. On the other hand, if the drawings are neatly cut off the board, and kept in a portfolio, they are constantly kept before the eye, and the student is thus reminded of subjects and of principles,

which would otherwise have formed only a single study, possibly never to be looked at again. Portfolios may now be had at a very low price, and the student is assured that the amount will be very well laid out.

Having drawn the sections of the walls in Fig. 70, draw a horizontal line across from top to top, and projecting beyond the walls as far as the eaves at E E are intended to overhang the walls of the building.

failure, each fault will become worse and worse as the work proceeds, and the incorrectness will be so evident that he will have to give up the work in an incomplete state, thus wasting all the time and trouble that have been bestowed upon it.

If, however, the student, in making a drawing from any of the examples that have been brought under his notice, should find that either from inattention to some preliminary point of detail or miscalculation of the scale, he is going so far wrong

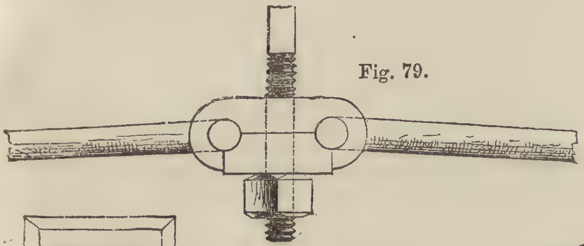


Fig. 79.

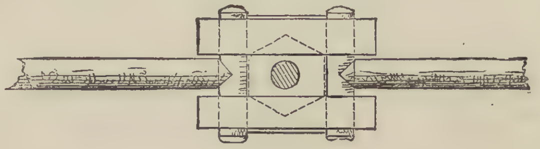


Fig. 80.

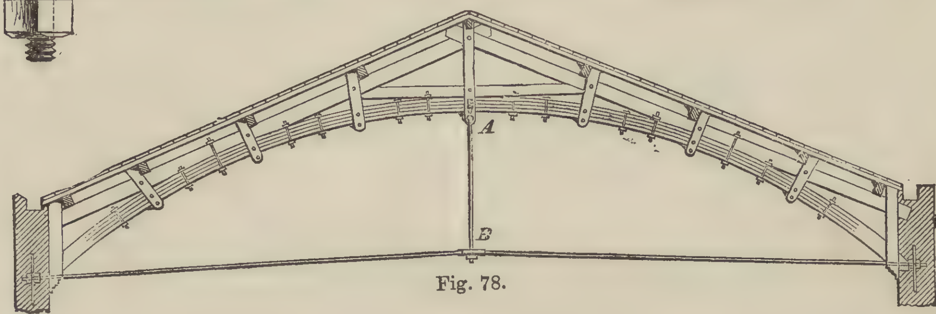


Fig. 78.

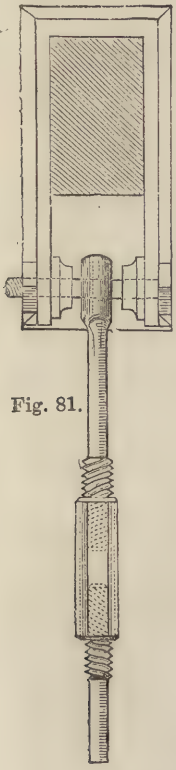


Fig. 81.

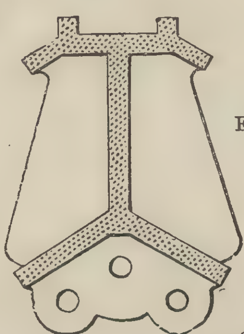


Fig. 76.

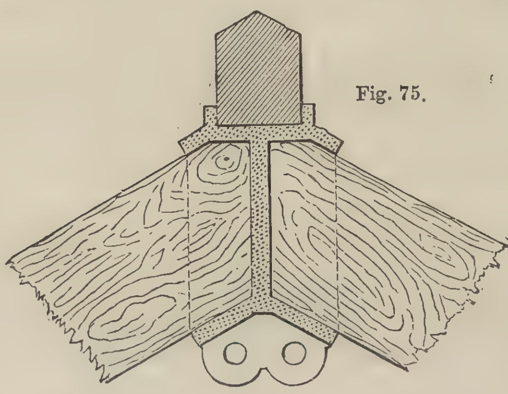


Fig. 75.

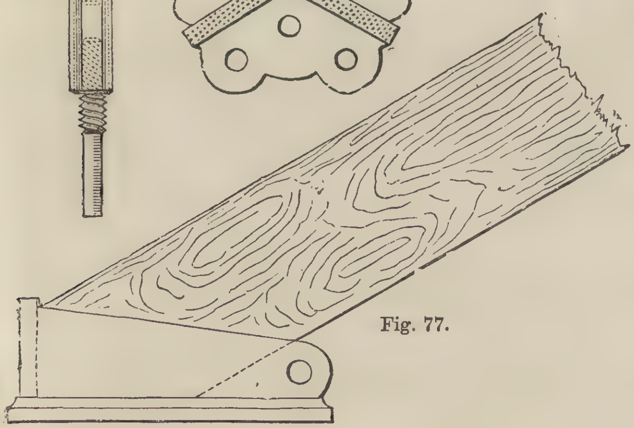


Fig. 77.

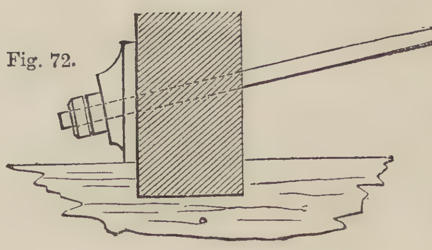


Fig. 72.

At the middle point of this horizontal erect a perpendicular, and mark on this the height of the angle where the rafters meet.

Next draw the rafters, the straining-pieces, D D, and the tension-rods, A A, B B, and the tie-rod C; then follow the purlins, and the rest of the roof, as shown in the example. The construction at the apex has been shown in Fig. 71, and this is to be followed in the complete drawing. The nuts at the ends of the rafters, too, are to be copied from Fig. 72.

The student is again urged to aim at absolute accuracy and refinement in his work, and is warned that unless he is very careful in the elementary operations the drawing will be a

that he is obliged to give up the piece of work that he is engaged on, he should not be discouraged, but renew the attempt on fresh paper until he has succeeded to his satisfaction. Perseverance, he must remember, never fails to bring its reward.

In drawing the ends of the purlins, for instance, the greatest care must be taken that they are all one size, and that the spaces between them are equal. This will be best accomplished by using two pairs of dividers, the one to be kept to the width of the purlins, and the other for the spaces. This will avoid the inaccuracy caused by frequently changing the size held in the instrument, and will be by far the more rapid plan.

VEGETABLE COMMERCIAL PRODUCTS.—V.

V. PLANTS USEFUL IN THE PREPARATION OF NUTRITIOUS AND STIMULATING BEVERAGES.

THE TEA-PLANT (*Thea viridis*, L., and *Thea Bohea*, L.; natural order, *Camelliaceæ*).—These two species are probably only varieties of the same plant. Native region, China and Japan.

The tea-plant is an evergreen shrub which attains in a state of nature a height of from twenty-five to thirty feet, but under cultivation seldom exceeds five or six feet in height, owing to the removal of its foliage by the cultivator. The leaves are alternate, short-petioled, smooth, shining, ovate-oblong, stiff and coriaceous, and slightly dentate.

All the numerous varieties of tea known in commerce are referable to one or other of the two grand divisions of green and black tea. Both are most undoubtedly produced by the same plant, the difference in their colour resulting simply from a difference in their mode of preparation.

The green teas comprise Twankay, so called after the name of a stream in Chehkiang, where this sort is produced; Hyson, or, in Chinese, *yu-tsien*, meaning "before the rains," in allusion to the time of gathering; Gunpowder, or *ma-chu*, "hemp-pearl," referring to the peculiar globular form into which the leaves are twisted; Imperial—the finest kind of green tea—so named because it is only used by the emperor and the mandarins: this tea consists of the smallest and most tender light-green leaves of the first gathering; it is not easily obtained in Europe in the pure state.

The black teas include Bohea, named with reference to the range of the Bu-i hills, where it is grown; Congou, or *koong-foo*, signifying labour or assiduity; Souchong, or *siau-chung*, meaning small or scarce sort; and Pekoe, or *pe-kow*, "white hairs," in allusion to the down on the epidermis of the young spring leaves. The two last are the finest and most expensive of the black teas.

The preparation of green tea may be described in general terms as follows:—The leaves are gathered from the shrub, and placed in bamboo baskets; they are then put into shallow iron pans, placed over charcoal fires, and stirred continually and briskly, the rising steam being fanned away; after this, they are removed from the pans, and whilst still flaccid with the contained moisture, are placed before the twisters, on a table made of split bamboo, and therefore presenting ridges; the twisters roll them over with their hands until twisted. The leaves are then spread out and exposed to the action of the air, and afterwards returned to the drying-pans, exposed there to additional heat, and kept continually stirred until the drying is complete, when they are picked, sifted, sorted, and so prepared for packing. Black tea is prepared in the same manner, with this difference, that the fresh leaves, as soon as collected, are thrown together into heaps, and allowed to lie until a slight degree of fermentation ensues, or a spontaneous heating, similar to that which takes place in a damp hay-stack. This partial fermentation of the tea-leaves darkens their colour. All the black teas are grown in Fokien, a hilly and populous district about 200 miles to the north-east of Canton. The green teas are raised in the district of Kianguan, about 750 miles from the same city.

Owing to certain peculiarities in Chinese legislation, landed property is much subdivided, so that the tea is generally cultivated in small gardens or plantations, the leaves being picked by the family of the cultivator. The first gathering takes place in early spring, in the month of April: pekoe and hyson are made from this crop. It is scarcely over before the air becomes charged with moisture, rain falls, and this, combined with the warmth of the atmosphere, causes the tea-shrubs soon to put forth, in the month of May, the leaves of the second crop. A third gathering is made about the middle of June, and a fourth in August. The leaves of the first gathering are the most valuable, and from these the finest imperial and hyson, with pekoe and similar qualities of black teas, are prepared. The leaves of the last crop are large and old, and consequently make preparations very inferior in flavour and value.

During the harvest season, when the weather is dry, the Chinese may be seen in little family groups on every hillside, engaged in gathering the tea-leaves. They strip off the leaves with astonishing rapidity, and throw them into small round baskets made for the purpose out of split bamboo or rattan. These baskets, when filled, are emptied into larger ones, and immediately conveyed to market, where a class of Chinese make it a business to collect them in large quantities, and partly manufacture them, drying them under a shed.

A second class, known as the tea-merchants, purchase the tea in this half-prepared state, and complete the manufacture, employing in the operation women and children. The tea-merchants begin to arrive in Canton about the middle of October, and the busy season continues until the beginning of March, being at the height in November, December, and January. The tea is brought to Canton either by land-carriage or by inland navigation. The roads are too bad to admit of beasts of burden attached to wheeled vehicles, so that the land-carriage is usually effected by porters.

In China tea is the common beverage of the people, being sold in the public-houses in every town, and along the public roads, like beer in England. It is quite common for travellers on foot to lay down their load, refresh themselves with a cup of warm tea, and then proceed on their journey. A Chinaman never drinks cold water, which he abhors and considers unholy; tea is his favourite drink from morning to night, not mixed with milk or sugar, but the essence of the herb itself, drawn out with pure water. The Chinese empire could hardly exist were it deprived of the tea-plant, so habituated are the people to its use; and there is no doubt that it adds greatly to their health and comfort as a nation.

The Japanese usually make tea by pouring boiling water on the leaves, after having first reduced them to powder. Neither the Chinese nor the Japanese use milk or sugar with tea; and certainly the peculiar taste and aroma of the tea are better appreciated without these additions.

Tea is imported in chests always lined with thin sheet-lead, and with a paper which the Chinese manufacture from the liber or inner bark of the paper mulberry (*Broussonetia papyrifera*, L.). It is silky in texture, straw-coloured, and made without size. When the tea is put into the boxes, it is pressed down first with the hand, and then with the feet, after which the boxes are nailed down and stamped with the name of the district-grower or manufacturer.

The Chinese colour with Prussian blue the teas which they ship for the foreign market. Only a little of this dye is employed, so that its use is not productive of evil results; still, the tea would be better without it. The Chinese never dye the teas which they retain for their own use. The green teas of commerce are too often only black teas coloured with Prussian blue. Nevertheless, comparatively speaking, very little adulteration of tea is practised by the Chinese. A few leaves of the *Camellia* and of a species of *Rhamnus* or buckthorn indigenous to China are found occasionally amongst the tea-leaves, but not to any very great extent. The leaves of such British plants as the beech, elm, willow, poplar, hawthorn, and sloe, are far more abundant, proving that the tea is adulterated after it has arrived in this country. The adulteration is easily detected by comparing the leaves from the teapot with the genuine tea-leaf. Tea is also adulterated with old exhausted tea-leaves, which are re-dried and used again.

In 1866, 139,610,044 lb. of tea were imported into the United Kingdom, of which quantity 102,265,531 lb. were retained for home consumption; in the same year we exported 20,245,454 lb. to foreign parts.

The consumption of tea by the Chinese themselves is enormous. They drink four times as much as we do. With rich and poor of all that swarming population, tea—not such as our working classes here drink, but fresh and strong, and with no second watering—accompanies every meal. The population of China, according to an official census taken in 1825, was 352,866,012, which is more than ten times our population. Estimating our annual consumption of tea at 33,600,000 lb., that of China must be forty times that quantity, or 1,444,000,000 lb. In addition to this there is a very heavy exportation in native vessels from China to all parts of the East where Chinese emigrants are settled, such as Tonquin, Cochin-China, Cambodia, Siam, the Philippines, Borneo, the settlements in the Straits of Malacca, California, and Australia. In comparison with such an enormous amount as this our own consumption sinks into insignificance.

The caravan or Russian teas are the best and most expensive of those used in Europe. They are brought overland from China by Russian merchants, who go there annually in caravans, *viâ*

Kyachta. These caravan teas, purchased by the wealthier Russian families, are preferred to those shipped in Canton, which are said to deteriorate in some degree through the sea air, and from being stowed away in the narrow and close holds of the vessels.

Tea was first brought to Europe by the Dutch in 1610, and they had for a long time the monopoly of the trade. But the British East India Company, entering the field as a competitor, soon obtained a fair share of the business. The sole object of the company was to provide tea for the English market; of this they had the exclusive monopoly until 1834, when the British Government passed an Act which threw open the tea-trade to all disposed to engage in this important branch of commerce.

Formerly all the tea received in Europe was cultivated exclusively by the Chinese; now the culture of the tea-shrub is successfully carried on in other countries.

The Dutch were the first to break the charm of the Chinese monopoly by introducing and cultivating the tea-plant in the rich and fertile island of Java. Their first experiment was so successful that numerous tea-gardens were soon under cultivation on the mountain range which runs through the centre of the island, where the plant escapes the scorching heat of the torrid zone, and finds a climate by height, rather than by latitude, adapted to its nature. A considerable quantity of tea is now annually shipped from Java to Amsterdam.

In 1810 an attempt was made to cultivate the tea-shrub in the Brazils, near Rio de Janeiro, and a colony of Chinese were induced to settle there, and attend to the plantations. But the experiment did not succeed: the shrubs became diseased, and the Chinese formally abandoned them. Another effort made in the same country in 1817 was unsuccessful, owing to difficulties arising from climate, the high price of labour, and the natural indolence of the natives. The experiment, however, was tried once more, and this time successfully, and tea culture is now prosecuted with energy in the Brazils, and with a commensurate amount of success. The Rio Janeiro market is entirely supplied with tea of domestic growth, and the public of Brazil are satisfied that no plant is more profitable or deserving of attention.

Tea is now cultivated in British India. Some years ago it was discovered that the tea-plant was indigenous to our Indian territory of Upper Assam. This plant, supposed to be a distinct species, has received the name of *Thea Assamica.* It is a more vigorous plant than the Chinese species, and has much larger leaves. It grows in the warm, moist valleys of the Himalaya mountains, the temperature and other conditions there being similar to the circumstances under which the Chinese plant is raised. The Assam Tea Company was started, and several thousand acres were soon under cultivation in the district stretching from Kumaon to the *hill tracts* acquired from the Sikhs. The plants grown are chiefly those raised from Chinese seed, the remainder are the indigenous plants of the district. The seeds of the Chinese plant were obtained by Mr. Fortune in China in the summer of 1850, and by him planted in Wardian cases. They germinated during the voyage, and reached their final destination—the plantations of the Himalayas—in fine condition. About 14,000 plants were thus added to the Assam collection. Chinese tea-curers have been induced to settle in Assam, and both black and green tea are now manufactured from the Chinese and Assam plants. The latter produces a very strong tea, which answers well to mix with the low sorts of China tea, and is chiefly used for this purpose. Several large cargoes of tea from Assam have already been received in this country. Land suitable for the culture of tea exists amongst the Himalayas to an almost unlimited extent, and the quantity raised annually and exported must increase as the plantations are extended and multiplied.

OPTICAL INSTRUMENTS.—II.

By Samuel Highley.

THE ABNORMAL EYE.

Having described the characteristics of the perfect and healthy organ of vision, we have now to describe the deviations from the normal eye, and those defects or diseases that require the optician's aid for their correction or alleviation. Between thirty and fifty years of age indications of natural decay in the perfect organ of sight may be detected, and it will be found, as a rule, that while distant objects are as distinctly discernible as in youth, it becomes necessary to hold *near objects*—such as the newspaper, needlework, etc.—further from the eye than the person has hitherto been accustomed to do, especially at candle or gas light—it is, in fact, becoming *long-sighted.* The average distance for distinct vision for near objects in the normal eye is about eight inches from the eye; but on long-sightedness setting in, near objects cannot be distinctly discerned till removed to a distance of fourteen, sixteen, eighteen inches, or further, from it. This defect is termed *presbyopia.* The commencement and progress of this deterioration of the normal eye depends upon how it has been used, and upon the health of the individual. At thirty years of age some eyes are more defective than others are at fifty years, but the average period of the commencement of decay in the eye is about the forty-fifth year, and is first indicated by feeling the necessity of removing small type further from the eye when reading by candle or gas light, and the consequent necessity for using spectacles. This will be about a year before their assistance during daylight is recognised as absolutely essential for the comfort of the organs of vision.

Presbyopia, it may be stated, is often accompanied by that "weakness of sight" termed *amblyopia;* and the latter is sometimes mistaken for the former, as the amblyopic person also cannot see small objects distinctly, and convex spectacles (as with presbyopia) improve his vision by affording larger retinal images; but the purely presbyopic eye is free from amblyopia.

About the age of fifty the far point, in the normal eye, also begins to recede somewhat, so that the eye then becomes slightly hypermetropic (or of the defective nature next described), and with increasing years may become absolute, so that the patient is not only unable to accommodate for divergent rays from near objects, but even for parallel rays from distant objects.

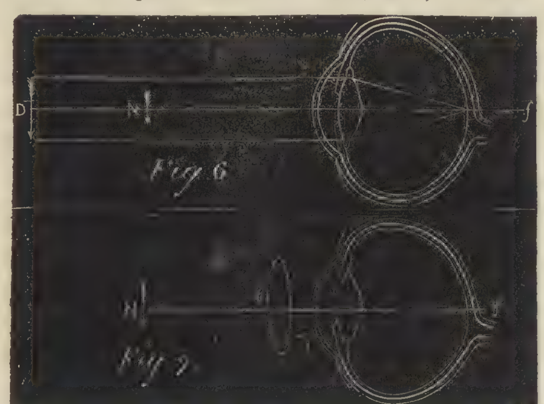
Another shortcoming, which may be present in youth, is where the eye, when in a state of rest, is incapable of bringing the parallel rays emanating from *distant* objects to a distinct focus on the retina, and can only do so by an effort of accommodation more or less considerable, according to the amount of defect, while no great inconvenience may be experienced in regard to near objects, when reading, writing, sewing, etc.—in fact, may never be detected till age sends the person so affected to the optician, or oculist, especially if he has good accommodative power, when the defect is unconsciously corrected with but slight effort. If, however, this defect is absolute, vision will not be perfect at any point. This is termed *hypermetropia,* an affection which was little noticed, or not properly understood, until within the last few years. Another deviation from the normal eye (which has no connection with age, but is, as a rule, a natural, often hereditary defect from birth, though seldom discovered by the person so affected till the age of puberty, or till the commencement of earnest study, or occupation at some trade or profession involving the use of the eye at its near point, or in other cases resulting from occupations teazing to the eyes) is *short-sightedness,* or *myopia,* as it is professionally termed. In this case persons can see the very smallest object perfectly when brought unnaturally close to the eye, while large ones at a distance, or even a moderate distance, are involved in such haziness, that they would not be justified in swearing to the recognition of an accused person in a court of justice.

All eyes—the emmetropic,* hypermetropic, and myopic—suffer change in the near point with the advent of old age. The eye is not adjusted at the same time for equally distant *horizontal* and *vertical* objects, being greater for horizontal lines than vertical ones, which may be proved in the following manner:—Draw on paper two ink lines at right angles to each other, and place one horizontal. At the distance of distinct vision, this will appear black and sharp, while the other will be indistinct, as if drawn in paler ink; adjust the eye for the vertical line, and the effect will be reversed. In some cases this difference in the curvature of the eye in two directions may become so great as to require optical correction by means of "cylindrical lenses." This defect is termed *astigmatism.*

Some persons (always affected with slight myopia) complain that after reading for a short time without glasses, the letters become confused, blurred, and appear to run into each other;

* The presbyopic is classed with the emmetropic eye, being in fact a normal eye defective through age and not by congenital malformation.

pain in the eye and around the orbit is experienced, and, if persisted in, the eyes become red and watery. After resting the eyes for a few minutes, reading may be proceeded with, but only to entail a speedy return of the same train of symptoms. If we request such a patient to look at our own forefinger, while we gradually approach it towards his eye, we shall find that when it is within a distance of about six inches, one eye becomes a little unsteady in its fixedness, and then gradually, suddenly, or spasmodically deviates outwards. Again, this deviation occurs even, perhaps, if the object be some feet distant, when we cover one eye, so as to exclude it from participating in the act of vision of the other. This outward deviation indicates insufficiency or weakness in the *recti interni* muscles of the eyeball, which tends to the production of double images of the objects observed (or what is professionally termed *diplopia*), which the patient intuitively suppresses, unless the object be brought too near to the eye. If such a person persists in employing the eye on near objects, the affected eye moves outwards and produces a permanent divergent squint (*strabismus*), in which case the patient again suppresses the image of the squinting eye, to avoid the production of diplopia, which leads to more or less of that "weakness of sight" of the affected eye termed *asthenopia*. By the judicious selection and employment of prisms of suitable refractive power, this weakness of the muscles, if attacked in *the early stages*, may be cured, and thus the surgical operation of tenotomy may be avoided. Such prisms must be weak at first, and then be

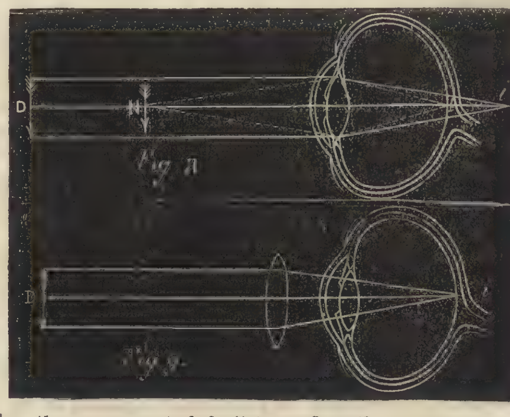


gradually increased in power. The prism must be placed with the base outwards before the affected eye, so that the rays from a candle, placed about eight inches distant, may fall upon a portion of the retina slightly to the outer side of what is known as the yellow spot (*fovea centralis*). To avoid the production of double images arising from this, the eye will instinctively move inwards, in order to bring the rays exactly upon the yellow spot. During these exercises of the internal rectus, short-sighted eyes must be furnished with concave spectacles, so that the object may be distinctly seen. This mode of treatment requires great patience on the part of oculist and patient.

Oculists classify eyes according to their diopteric characteristics when tested for their *furthest point* of distinct vision, and four kinds may be specified :—

1. The *Normal*, or *Emmetropic Eye*, in which, when in a state of rest, parallel rays are brought to a focus *on* the retina, as shown at *i* (Fig. 2, page 111).

2. The *Presbyopic*, or *Long-sighted Eye* (aged emmetropic), in which, through the loss of accommodative power, caused partly by the weakening of the ciliary muscles, partly by the hardening and discolouration of the crystalline lens,* and the flattening of the cornea, the faculty of bringing *near objects* to a focus on the retina is lost, unless the object be removed to an abnormal distance from the eye; though the eye, in a state of rest, is capable of bringing *parallel rays* emanating from a distant object to a focus *on* the retina, and so far is a normal eye still, while the converging rays from a near object come to a focus behind the retina, as shown in Fig. 6. This defect is remedied by holding the object at a distance from the eye, so as to lessen the divergence of its rays, or by placing a convex lens

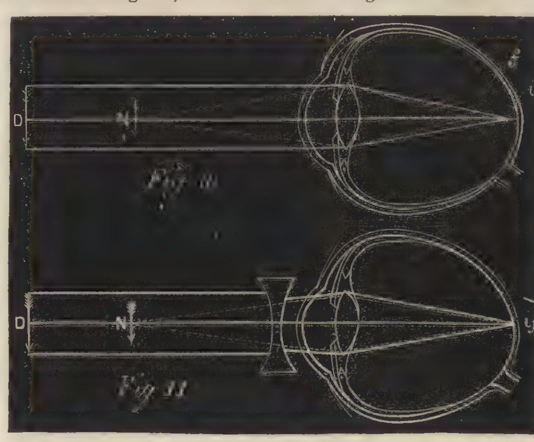


before the eye, so as to help it to produce the necessary convergence, as shown by the dotted lines in Fig. 7.

3. The *Hypermetropic*, or *Over-sighted Eye* (*hyperpresbyopic*, or *hyperopic*), which is adjusted for convergent rays, but in which parallel rays are brought to a focus *behind the retina* when the eye is in a state of rest, as shown in Fig. 8. This results from the length of the axis being too short—in other words, the retina being too near the cornea—or through the refracting surfaces of the eye being slightly flattened, or both causes may be co-existent. In either instance the refracting part of the organ of vision is incapable of converging parallel rays from a distant object, so as to bring them to a focus on the retina. The *hypermetropic* eye may be diagnosed by its peculiar shape, as it appears flatter and shorter than the normal eye, and it does not fill out the aperture of the lid, a little pouch being left between the eyeball and lid.

Hypermetropia is remedied by placing a convex lens before the eye, so as to help it to produce the necessary convergence of the parallel rays, and bring them to a focus on the retina, as shown by the lines (Fig. 9).

4. The *Myopic*, or *Short-sighted Eye* (*brachymetropic*), which, when in a state of rest, is adjusted for divergent rays, and wherein parallel rays are, even when the eye accommodates itself for its farthest point, brought to a focus before the retina, as shown in Fig. 10, so that distinct images are formed on the



retina only when the rays emanating from such object fall upon the eye divergently.

This results from the axis of the eye being too long, or the curvature of the refracting surfaces being too great. This defect is remedied by holding the object very close to the eye, so as to increase the divergence of its rays, or by placing a concave lens before the eye, so as to produce the necessary divergence, as shown by the dotted lines (Fig. 11).

* The crystalline lens is as transparent as water till about the twenty-fifth or thirtieth year, when it begins to be slightly tinged with yellow towards its centre, which very gradually extends towards the surface, and becomes deeper and deeper in tint, till in extreme old age it may resemble a piece of yellow amber.

FORTIFICATION.—III.

BY AN OFFICER OF THE ROYAL ENGINEERS.

PROFILES OF HASTY AND IRREGULAR DEFENCES.

The destructive effects of rifled arms render it absolutely necessary that cover of some kind should be rapidly provided for the troops acting on the defensive, and it must often happen that a regular profile cannot be given to works only intended for the temporary occupation of a field of battle.

Advantage must then be taken of all such materials existing on the spot (walls, hedges, etc.), as are capable of being readily converted into parapets; and where no such materials exist, cover must be obtained by means of what are called Shelter Trenches (Fig. 15). The object of these is to secure for the defenders, by a small amount of labour, considerable protection whilst firing (as may be seen by comparing the men shown in the open in the figure and those in the trench); and, at the same time, not to obstruct their rapid advance when the moment for a forward movement arrives. The method of executing them is as follows:—As soon as a regiment arrives on the ground it is intended to defend, one rank is extended as a line of workmen, at six feet intervals from one another. In the first instance, a continuous trench 1 foot 3 inches deep, and 2 feet broad, is dug, the earth being thrown in front to form a parapet 1 foot 3 inches high. This trench can be excavated in from ten to twenty minutes, and is then capable of giving cover to one rank kneeling in it, and to a rear rank lying down on the ground behind (Fig. 16).

If more time is available, the trench is then gradually widened until it is 7 feet broad, when it is wide enough to allow of the men lying down in it, and being perfectly hidden until required to fire (Fig. 17).

As soon as it is 4 feet wide, there is room for both ranks kneeling. No tracing or special measurements are necessary for this work; for if the men are placed in line, two full paces apart, they can measure the depth and breadth sufficiently accurately with the blades of their shovels, which are about 1 foot in length. Care must be taken that after the parapet has been raised to a height of 1 foot 6 inches, the additional earth is not allowed to increase this height, as it would then be too high to be fired over by men kneeling in the trench. In rear of each company, short trenches will be dug for the officers and non-commissioned officers (Fig. 17), who will then be in their right places for superintending the firing, and only so far back from the line, that when the main trench is completed, their own parapet shall not be interfered with.

As will be seen in the accompanying cuts, the men in these trenches are much less exposed than those in the open, and as they are absolutely out of sight when lying down and not actually engaged, many lives must be saved by the cover they afford; at the same time the proportion of fatal wounds to the total numbers of men hit must be larger than before, since the men's heads are almost the only parts exposed. This result appears to have been noticed in some of the late battles in France, where trenches of this description were employed. In woods, where large trees can be easily obtained, parapets may be formed by felling the trees, and, after removing the branches, laying them lengthways one above another, as represented in Fig. 18. If shovels are available, a small trench should be excavated, and the earth thrown over the logs. A very serviceable parapet may thus be readily formed, as the crest, which is usually the weak part of all earthen parapets, is in this case quite bullet-proof.

The intrenchments used by the Maories or New Zealanders are worthy of notice, both on account of their being somewhat different from the ordinary profile, and also because the same method may be advantageously applied in cases where it is desirable to defend a hill-side with several rows of men in shelter trenches, one behind the other. Their pahs, or intrenched positions, were generally admirably chosen on the slopes of hills, inaccessible or difficult of approach, and the

Fig. 18.

Fig. 15.

Fig. 16.

SCALE 40′ TO 1 INCH. Fig. 19.

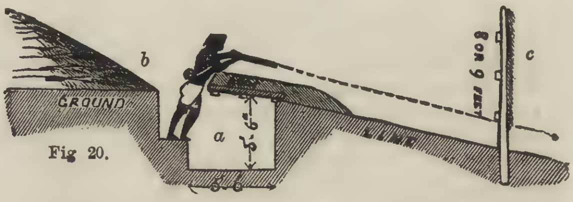


Fig 20.

SCALE $\frac{1}{120}$.

SCALE $\frac{1}{60}$. Fig. 17.

SCALE $\frac{1}{240}$. Fig. 23.

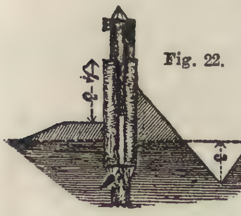


Fig. 22.

SCALE $\frac{1}{108}$.

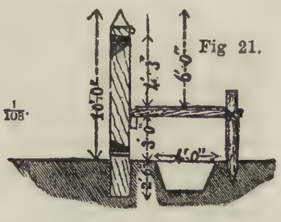


Fig 21.

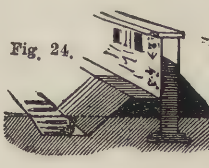


Fig. 24.

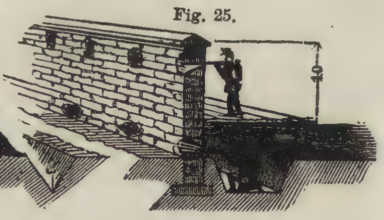


Fig. 25.

ground most liable to attack thoroughly well swept by their fire. These works generally consisted of an irregular line of deep rifle-pits, as represented in Figs. 19*a*, 20*a*, placed close to one another, connected either by a trench (*b*) or a small underground passage, and the earth being thrown up *behind* the trench instead of in front, as is usually the case. This mound served the double purpose of affording cover to their huts and dwelling-places, and, if necessary, could be manned to bring a second line of fire to bear on the attack. The men in the pits, firing at the level of the ground, were very little exposed, besides which the narrowness of the pits and their irregular outline made it difficult to dislodge the defenders by the fire of shells. The front was usually protected by a stout palisade, or post-and-rail fence, on which a screen of flax was hung (*c*)—the former as an obstacle to prevent the assailants closing with the men in the pits, who were hidden from view by the screen, and were able to fire under it close along the ground. Some of the pits were partially roofed in and lined with fern to serve as sleeping-places, as may be seen from the enlarged section through rifle-pit in Fig. 20. An interesting detailed account of these may be found in Vols. VI. and XIV. of the "Professional Papers of the Royal Engineers."

Stoccades are formidable parapets constructed entirely of wood in situations not exposed to artillery fire. They are so high as to necessitate the use of ladders to get over them, and being bullet-proof and loopholed are troublesome to attack, as unless they can be approached by surprise, many casualties must occur in attempting either to escalade them, or to blow them in with gunpowder.

Stoccades are the type of work usually met with in wars with uncivilised nations who do not possess artillery, such as the Hill tribes on our Indian frontiers, etc. One of these works in Bhootan proved a very formidable obstacle, formed of long bamboos firmly lashed together, and was not demolished by the explosion of 60 lb. of powder placed in a bag against its foot. Ordinary stoccades consist of a row of upright timbers 12 or 14 inches in diameter, and from 10 to 15 feet in length, placed touching one another, with their butt ends buried in a trench 3 or 4 feet deep. These logs are kept together by being spiked to two rails, or cross-pieces, near the top and bottom of the logs on the inside (Fig. 21).

To increase the difficulty of getting over them, their tops should be pointed, and where they come in contact the logs should be squared, by having slabs cut off each side.

If this cannot be done, smaller logs should be placed in front and in rear, to strengthen the weak points between the large timbers.

The larger the logs are the better, both on account of the greater security they afford, and also because they are not so liable to be dangerously weakened by cutting a loophole through them. This is generally managed by cutting a notch equal to half a loophole out of each of two adjacent logs, and placing them together.

As the usual method of demolishing a stoccade is by exploding bags of powder placed against them, it is desirable to prevent this as far as possible, by digging a ditch in front, and piling the earth at a steep slope against the stoccade on the outside. This should generally be done, unless the lower portion of the stoccade requires to be loopholed so as to allow of a second tier of musketry fire, when a temporary platform or "banquette" must be erected inside to enable one row of men to fire over it, while another rank stand in a trench at the first of the timbers, and fire through close to the ground level (Fig. 22).

With regard to loopholes generally, it will be well to remember that they should invariably be made at a level either too high or too low for the enemy to use for firing into the work from the outside; and, at the same time, they must be at a convenient height on the inside for use by the defenders. About 15 feet of ordinary stoccade work can be constructed by a party of eight men in eight hours. This does not include cutting down, or bringing the timber to the spot. Strong hedges afford excellent defensive obstacles, and are capable of being converted with little trouble into good parapets.

When a hedge is less than 6 feet high, a ditch should be dug, and the earth thrown over to the other side to form a parapet, as the hedge is then utilised as an obstacle, and also as a revetment to the earth behind (Fig. 23*a*). This method gives the men firing over the hedge a command over their assailants.

When time presses, and the hedge is high and strong enough to form a good obstacle, a slight trench with the earth piled against the hedge will suffice to obtain cover. A small ditch (Fig. 23*b*) should be added outside to keep the enemy from closing with the breastwork. In some instances it will be better to make the trench deeper, and having cut away the lower branches, to fire close to the ground (Fig. 23*c*). Hedges intended as obstacles may be very much strengthened, and made difficult to cut down, by having thick iron wire run through them and made fast to the largest trees in the hedge. As it is the exception to find hedges without some sort of bank or ditch on one side of them, the excavations that have been indicated in these diagrams will generally require very slight work to complete, and consequently this species of defence may be very rapidly prepared.

Walls of moderate thickness may be rendered defensible by either breaking loopholes through them at the required levels, or cutting openings down from the top, care being taken that the wall is not too much weakened by this treatment, and that the enemy is prevented from closing with the loopholes from outside.

On level ground, walls under four feet high are useless as parapets, but may be of service as a partial revetment to earthen ones thrown up in front of them (Fig. 24).

Low walls, under 7 feet high, require that a ditch and a trench should be dug in order to obtain sufficient cover. High walls may be arranged for two tiers of musketry fire, in the same way as has been described for a stoccade (Fig. 25).

In the hasty defence of villages and towns, rough barricades formed of carts, furniture, etc., may be employed both as obstacles and parapets. No rules can be laid down for their construction, except that they should be placed at points where their fire can be assisted from loopholes in adjacent buildings, and where artillery fire cannot be brought to bear on them from a distance. Four-wheeled carts filled with stones, earth, etc., would form a good commencement for a barricade if drawn up in a line across a street, and their hind wheels taken off. Behind these, logs of wood, sacks filled with coals, barrels, etc., would be accumulated until a sufficient parapet and banquette had been formed; a pile of broken wheelbarrows, furniture, etc., being arranged in front as an obstacle, but so as not to afford cover.

TECHNICAL EDUCATION ON THE CONTINENT.—VI.

BY ELLIS A. DAVIDSON.

THE POLYTECHNIC SCHOOL AT HANOVER (*continued*).

Having thus given an outline of the comprehensive course of studies carried out in this school, which may be termed a Technical University, it is now only necessary to mention that the courses are arranged for each student according to the profession he intends following, the technical or special branches, however, not being taken up in the Higher School until the complete general course in the Lower School has been gone through.

REGULATIONS AS TO CONDUCT AND DISCIPLINE, ESTABLISHED BY DECREE OF THE MINISTER OF THE INTERIOR.

The regulations of this school are so admirable in their character that they are calculated to exercise as great an influence over the general life and moral training, as the course of study has upon the intellectual career of the student. An extract only from the code of rules will be given here with the view of showing that in the conduct of such establishments for youth there are other subjects to be considered than the mere course of studies.

1. The students and persons attending the Polytechnic School must conduct themselves in a decorous and blameless manner, and must show the lecturers, teachers, and other persons concerned in the management, the utmost obedience and respect.

2. They must, during lectures and lessons, be orderly and attentive, and must be in their places in the class or lecture room before ten minutes after the time fixed. The cause of absence must in every case be explained in writing, and in case of illness a medical certificate must be produced.

3. Each student must provide such books, or other school material, as the teacher may prescribe, without delay.

4. The exercises and notes given out by the lecturers and teachers to be worked out in leisure hours, must be carefully prepared and delivered at the specified time.

5. The students in the Lower School must, as a body, take the entire course of studies, unless exempted from any branches by permission of the Direction. In the Upper School the students are free to select the classes or lectures they may wish to attend; but they are urged to avoid disturbing the course laid down for each profession, since each branch has necessarily an important bearing upon the other. A student, however, having entered himself for any complete course, is not permitted to omit any individual subject comprised in it without written permission of the professor.

6. Models, tools, apparatus, examples, etc., used in the lectures and lessons, must be carefully preserved, and any damage thereto must at once be made good. Where the individual student is not discovered, the entire class is held responsible for restoration of damaged property. Students are not allowed to take books or examples home, unless by special permission.

7. The school buildings, furniture, and fittings must also be kept from damage, under the previous rule.

8. Proper obedience must be shown to the officers and attendants, whose duty it is to carry out the rules and to maintain the order of the establishment outside the class-rooms. Violations of this rule are reported to the Direction.

9. Students wishing to form amongst themselves a club or union, are permitted to do so provided their object be their mental, moral, and social benefit. The rules of such union must be submitted for the approval of the Direction, and every student under age wishing to join must present the written permission of his parent or guardian. The members are free to withdraw themselves from such union at any time, but new members can only join at the commencement of a school year.

10. Disorderly conduct of any kind is severely punished.

11. Improper conduct in the streets, or any other public place, although it may not be absolutely legislated for in the code of regulations, will be recognised and punished as compromising the reputation of the school, causing annoyance, and setting an evil example to others.

The means taken to secure discipline are—

(*a.*) Warning of dismissal.

(*b.*) Suspension from a class.

(*c.*) Dismissal from the school.

(*d.*) Formal expulsion.

The extreme punishments are, however, never inflicted without frequent admonitions and warnings, and in every case the parents or guardians are communicated with.

SUPERVISION OF STUDENTS.

It is incumbent on every teacher of lower classes in the Polytechnic School to exercise the most careful supervision over the students, and to register their attendance. It is also the teachers' duty to keep a continuous watch over the conduct and attention of the students, so that they may be prepared at the end of the year to give an accurate and truthful report of each.

THE LABORATORY.

The laboratory is open for the use of students at stated hours. Experiments or processes, which could not otherwise be completed by dinner-time, are begun at eight in the morning. Except under special circumstances, only such work as is prescribed by the teachers is allowed to be done in the laboratory. The laboratory is well supplied with complete apparatus, etc., for carrying out experiments on a large scale, and for lecture purposes; but the students are required to provide themselves with the smaller utensils—test-tubes, beakers, flasks, funnels, and other apparatus. The laboratory students are supplied with a certain quantity of spirits of wine (for lamps), filter paper, litmus paper, etc. Students requiring more must purchase it.

Such students as desire the accommodation can be supplied with a complete set of glass beakers for a moderate sum, which is returned to them at the end of the school year, if the glasses are restored unbroken.

The chemicals students may require for their private study may be purchased at numerous shops, or can be supplied at moderate prices from the laboratory; the payment must, however, be "cash," the laboratory not undertaking to keep credit accounts of goods supplied.

For the maintenance of proper order, for the economy of the laboratory, and to render its resources as widely beneficial as possible, the following rules have been established, and these are given here, as indeed are all the other details, in order to afford hints for the establishment of similar institutions in this country.

1. Each student must keep his own place in the laboratory in order, and before leaving must restore the apparatus he has used to its proper place, so that it may be ready for the next comer.

2. Such apparatus as may be the property of the student, or which has been specially entrusted to his care, may be locked up in cabinets.

3. The students are bound to see that under no circumstances whatever is anything put into the jars or bottles but the chemical stated on the label, and to be careful that the proper stoppers are put in the bottles, so that the purity of the contents may not be impaired, or that evaporation may not take place through inaccurate fitting of the stoppers or covers.

4. The apparatus in the lecture theatre are reserved for lectures, and must not be removed for any other purpose.

5. Although according to a previous regulation students are bound to make good any damage done to the school property, this rule, in consideration of the fragile nature of some of the chemical apparatus, and the dangers to which they are subjected whilst in legitimate use in the laboratory, is thus far relaxed, that payment is only exacted when the damage has been kept secret, or is proved to have taken place through absolute neglect.

In the following cases, however, full restitution is demanded:

(*a.*) Where a student has injured the balances used, so that repairs are necessary.

(*b.*) When any of the apparatus has been so damaged as to be of no further use.

(*c.*) When books of reference used in the laboratory have been soiled or stained.

(*d.*) When the hand-towels have been used for wiping up acids, or subjected to other destructive treatment.

A fine is also inflicted on students leaving gas burning in the laboratory, or neglecting to see that the taps are properly turned off.

The teaching staff in this admirable institution comprises above forty professors—not professors in name only, but absolutely professional men of the highest position, architects, consulting engineers, analytical chemists, and mathematicians; and the inspectors are all practical men, appointed by the Direction for their status in the branch in which they are to examine.

In addition to the various branches of science and art already mentioned, classes are held for instruction in languages and other subjects connected with the intellectual development of the students, and which serve to promote their progress in either their own country or any other. Amongst these are—languages, English, French, etc.; building arts; history—not merely of their own country, but universal history—and social science.

Some statistics in relation to this Technical University, which may be taken as a type of what such an institution should be, cannot fail to be interesting to the reader. In the year 1869-70 the Polytechnic School was attended by 384 persons, of whom 197 were students of the previous year and 187 were new; of this number 322 were regular students, and 62 persons admitted to individual courses of lectures; 88 entered the Lower, and 296 the Upper School. This shows that although the standard of the matriculation to the Upper School is very high, the Lower School is doing its work of preparation efficiently; and even more than this, it proves that the scientific culture in other schools in Germany must be of a most efficient character, for supposing that the whole of the 197 students remaining from the previous year had been drafted into the Upper School—which, as the courses of study in the Upper School extends over four or five years, is not likely—there would still remain 99 students who have been supplied by other schools, without counting the 62 who have

entered for special courses of lectures only, from whom, as already stated, no examination is demanded on entering; but it is evident that as all the lectures are of a sound and eminently practical character, and not likely to attract persons who could not follow the teaching and benefit thereby, the rudimentary teaching these have received must be of an efficient character.

It is necessary to say that the advantages of this institution have not been confined to Germany, but that students have entered from various parts of Europe; thus, the 384 students of 1870 are composed of 195 from the province of Hanover, 154 from other parts of Germany, 4 from Norway and Sweden, 5 from Russia, 2 from Finland, 4 from England, 12 from the Netherlands, 1 from Italy, and 7 from America.

The advantages to be derived from institutions of the kind we have just described cannot be rated too highly. Up to the present time nothing approaching the Polytechnic School of Hanover, either in constitution, management, or purpose, has been established in this country; but the movement in this direction in the establishment of the Whitworth Scholarships, and other aids to the advancement of practical science, will doubtless end in the formation of a university which shall stand in the same relation to art-knowledge and science that Oxford and Cambridge now occupy towards the learned professions.

LENDING AND REFERENCE LIBRARY.

The library is open on all week days from nine to twelve in the morning, and on Mondays, Tuesdays, Wednesdays, Thursdays, and Fridays, from half-past two to four o'clock in the afternoon.

The library is also open from twelve to one o'clock on all week days during vacations—a great privilege to students residing in the neighbourhood who may wish to consult some book of reference.

Students borrowing books are enjoined to take great care of them, and are strictly forbidden to make any notes or remarks on the pages; they are, however, requested, should they feel that any remark they might make, or any solution of a problem, etc., which may occur to them might be of service to others, to write the same on a separate slip of paper, and place it in the book.

The benefits of the library are not restricted to the students, but persons resident in Hanover and the neighbourhood are permitted to borrow books—an introduction and guarantee being signed by a householder or other person of position.

Persons borrowing books from the library are not allowed to lend them to others, without special permission in writing from the secretary of the library. The original borrower is still, however, held responsible for the book. He is required to sign the receipt for it, and to insert in it the name and address of the person for whom he is borrowing the book.

School books, dictionaries, and other books of reference are not lent out, neither are books of engravings. These are, however, allowed to be taken into the class-rooms when required for the purposes of study; but in that case they are considered as borrowed, and the proper receipt must be signed for them before they are taken from the library.

Having thus given a detailed account of this great Polytechnic University, we will next proceed to consider the extended system for the education of workmen and their children, and for this purpose we will describe the whole group of schools so efficiently carried on in the kingdom of Wurtemberg.

PROJECTION.—VIII.

SECTIONS OF CONES AND PENETRATIONS OF SOLIDS.

THE PARABOLA.

If a cone be cut by a plane parallel to one of the sides of the triangle which forms its elevation, the section is called a *parabola*.

Fig. 95.—*To draw the parabola which shall be the true shape of the section of the cone* A B C, *on the line* D E, *which is parallel to* C B.

Divide E D into any number of parts, in F G H, and through these points draw lines parallel to the base, meeting the sides of the triangle in *f*, *g*, *h*, *i* on each side. Now it will be evident that all sections of a *right* cone which are parallel to the base must be circles; and therefore, as the base A B of the elevation is represented in the plan by the circle A′ B′, the line *f f* in the elevation will be represented by the circle *f* in the plan; and similarly, the lines *g* and *h* in the elevation become the circles *g* and *h* in the plan.

From E in the elevation draw a perpendicular, which, passing through the plan, will give the line E′ E′. This is the line where the section-plane, entering the cone at D, will cut the base. A perpendicular dropped from D will mark on the diameter the plan of the top of the section—viz., D′.

An additional point, I, has been inserted between H and D, in order to gain more points for tracing the curve. This point is to be worked similarly to the others.

It has been shown that the section-plane cuts the elevations of circles *f g h i* in F G H I, and therefore perpendiculars dropped from these points to cut the plans of these circles, will give the points *f*, *g*, *h*, *i* in the plan. The curve drawn through these points, together with the straight line E′ E′, forms the *plan* of the parabola, being the view of the slanting surface E D as seen from a point of view immediately over the cone.

To draw the true shape of the section, draw a line D″ E″ parallel to D E, and from D, E, F, G, H, I draw lines at right angles to D E, passing through D″ E″ in F′, G′, H′, I′. On each side of these points, mark on the lines drawn through them the distances which the points E′, E′, *f*, *g*, *h* in the plan are from the diameter A B—viz., *f*, *g*, *h*. Through these points draw the curve, which will be the true parabola formed by the plane cutting the cone in the line D E.

THE HYPERBOLA.

Fig. 96.—When a cone is cut by a plane which is parallel to the axis, the section is called the *hyperbola*.

In this case the object of the lesson is to find the true section of the cone, caused by a plane, of which D E is the edge elevation, cutting it parallel to the axis. Rotate the cone on its axis so that the section shall face the spectator, in which position (Fig. 97) it will evidently be parallel to the vertical plane. Now from C in the plan, draw any number of circles, cutting the line *e e* in *f*, *g*, *h*. The diameters of these circles will be marked by the points *f′*, *g′*, *h′*. From these draw perpendiculars cutting the side of the cone; and the lines *f″*, *g″*, *h″* drawn parallel to the base will give their elevations. Now from the points in the plan where the section-line cuts the circles—viz., points *f*, *g*, *h*—draw perpendiculars cutting the lines *f″*, *g″*, *h″* in *f*, *g*, and *h*; then from D (Fig. 96) draw a line to cut the axis in D′, and perpendiculars from *e′ e′* to cut the base of the elevation in *e e*. The curve drawn through all these points will be the required hyperbola.

THE PENETRATION OF SOLIDS.

When one solid meets another it is said to *penetrate* it, and the development of the form generated at the intersection of the bodies is a study of the utmost importance to artisans. The lessons we are now giving on this subject commence with those of the most elementary character, and advance by very gradual stages. Only fundamental principles are, however, developed, in order to prepare the student for the advanced studies which will be given in subsequent lessons adapted to the respective branches of industry.

Fig. 98 represents the plan and elevation of a square prism penetrated by another of smaller size, their axes* being at right angles to each other, and two of their faces being parallel. The figure at this stage is so simple that it requires but little explanation. The points not visible in the present view, owing to their lying exactly beyond others, are marked with letters corresponding to those on the points which are in front of them, with the addition of a dash (′), and the points themselves will become visible in Fig. 99, where the object is rotated.

Fig. 99.—Place the plan at any angle (as required). The projection will then be accomplished, as in previous figures, by drawing perpendiculars from the points in the plan, and intersecting them by horizontals from the corresponding points in the elevation. Points G and H will mark the line of penetration—that is, the line at which the smaller prism enters the larger.

Fig. 100 is the development. The widths of the sides being equal to A B, and the length to the height of larger prism, the squares represent the cavities through which the smaller

* *Axes*, plural of *axis*.

prism would pass if the development were folded into a square form.

Fig. 101 represents the plan and elevation of a square prism penetrated by a smaller one, when the axis of the latter is at an angle to that of the former. The student who has followed the lessons to this point will find no difficulty in projecting the plan from the elevation, and by turning the plan, to project the view given in Fig. 102. The object, however, of the lesson is to show that, although the penetrating prism is *square*, the opening through which it is to pass, and which it is to *fill* up, is an *oblong*. The reason of this is, that although the width of the prism from E to F is not altered by being placed obliquely, the line A B across the side C D is longer than E F. Therefore, having developed the surface of the larger prism (Fig. 103), draw horizontals from A and B, which will give the top and bottom of the oblong, which is to be made of the width E F. The aperture on the opposite side is to be projected in the same manner from G H.

Fig. 104 shows the development of one of the ends of the smaller prism. Full directions for working this figure have already been given in Fig. 34.

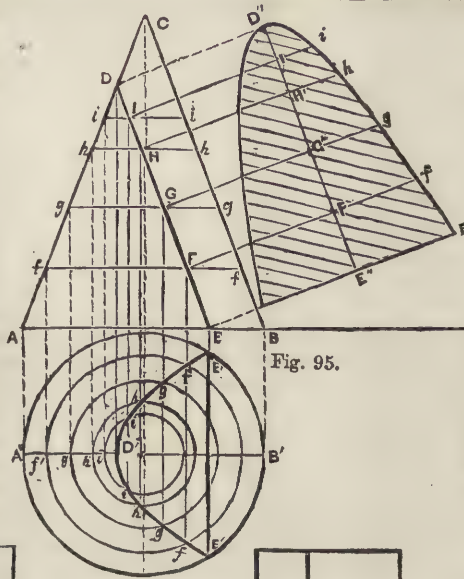


Fig. 95.

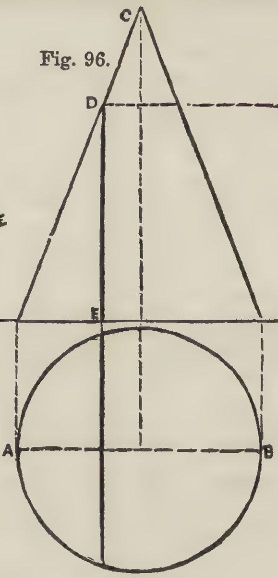


Fig. 96.

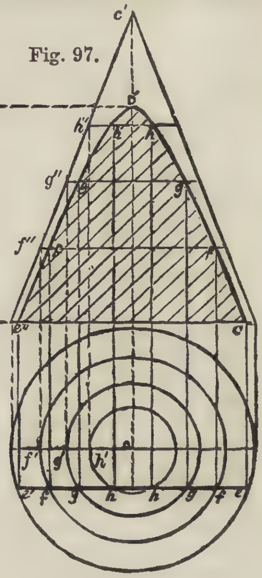


Fig. 97.

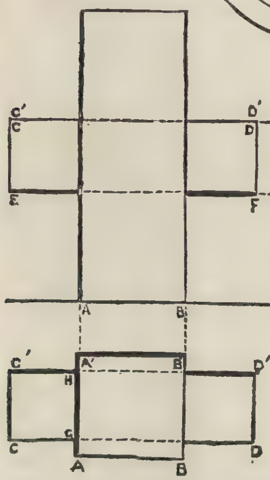


Fig. 98.

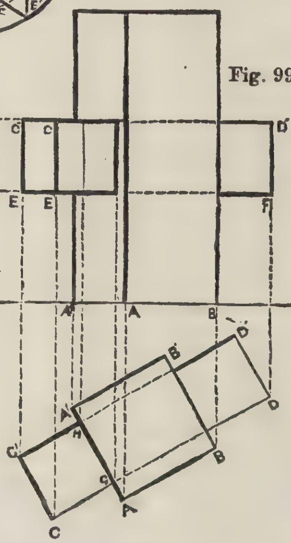


Fig. 99.

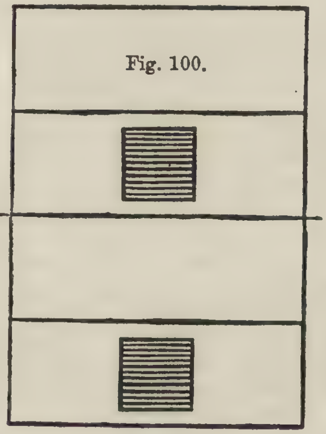


Fig. 100.

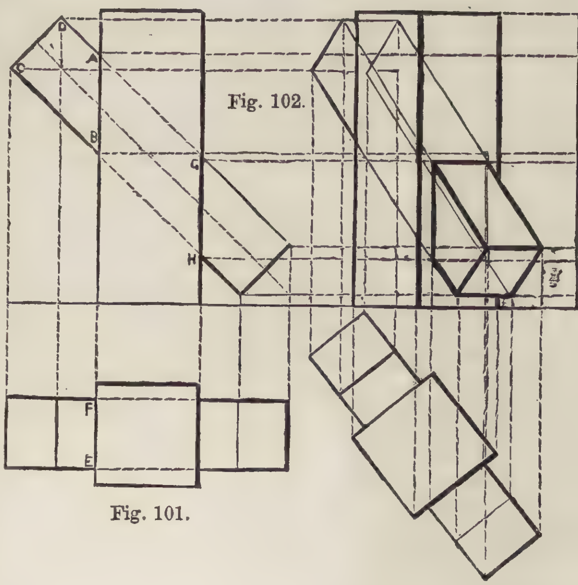


Fig. 102.

Fig. 101.

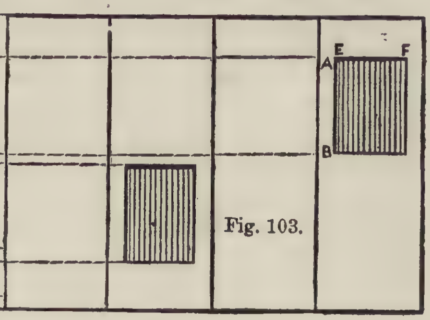


Fig. 103.

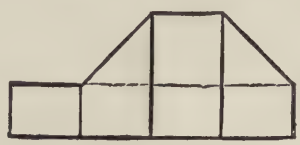


Fig. 104.

NOTABLE INVENTIONS AND INVENTORS.

III.—CLOCKS AND WATCHES.

BY JOHN TIMBS.

Although the action of the various machines used for measuring time is founded on the movements of bodies, and its principles are derived from arithmetic, mechanics, geometry, and physics, there can be no doubt that the heavenly bodies originally gave rise to the measurement of time, and that mankind was induced, from an observation of their motions, to adopt their present mode of dividing it. Sun-dials, which show apparent time, and clepsydræ, or water-clocks, which give a rude approximation to mean time, were the earliest machines used in the measurement of time. For this purpose also certain pieces of mechanism are kept in motion either by a falling weight, or by the elastic force of a spring, and which have received names varying according to the duties they have to perform; thus, the term time-piece is applied to any piece which is intended merely to mark the time without striking the hour; a clock is one, which in addition to showing the time, strikes every hour, on a bell or spring, a number of strokes corresponding to the hour of the day or night indicated by the hands at the time.

The sun-dial of King Ahaz, who lived about 742 years before Christ, is the first on record. The first constructed on mathematical principles was placed at Rome, B.C. 293, until which period the heavenly bodies appear to have been the only measure of time known to the Romans. The most perfect sun-dial was, however, unavailable when the atmosphere was charged with clouds; hence the dropping of water, being nearly a regular motion, was, at a remote period, applied to the measurement of time. About the year B.C. 145, Ctesibius of Alexandria invented a clepsydra, and he is even said to have applied toothed wheels to water-clocks. In the year A.D. 800 the Caliph Haroun al Raschid presented to the Emperor Charlemagne a clepsydra of gilded bronze, which is stated to have performed many wonders, altogether incredible; it is, however, the first time-keeper which is recorded to have struck the hour. Alfred the Great, we are told, measured time by burning wax-candles marked with circular lines to indicate the hours; but these must have been imperfect time-keepers.

By whom was first invented the clock with wheels having a balance, it is hard to say; it was, however, originally called a *horologe*, the word *clock* (probably derived from the French *cloche*, a bell) being applied even so late as the fourteenth century to the bell which was rung to announce certain hours indicated by the sun-dial or clepsydra. The word *horologe* being formerly applied indiscriminately to a dial as well as a clock, nothing decisive can be inferred from its use. A method of making clocks without the assistance of water was known about the year 1129, and they were set up in churches as early as 1174. Towards the middle of the thirteenth century a Saracen is stated to have received a sum equal to £2,000 for having made a clock moved by weights. This machine was afterwards presented to Frederick II., Emperor of Germany.

The first author who has applied the term *horologe* to a clock appears to be Dante, who was born in 1265, and died in 1321. It would thus appear that striking clocks were known in Italy as early as the latter part of the thirteenth or beginning of the fourteenth century. In the reign of Henry VI. a pension was granted to the Dean and Chapter of St. Stephen's for taking charge of a clock placed in a turret in Palace Yard, opposite to Westminster Hall, which clock was the work of an English artist. It was erected in the time of Edward I., A.D. 1288, from a fine imposed on the Chief Justice of the King's Bench. This famous *clochard*, or bell-tower, was built in the reign of Edward III., 1365-6, and Henry VI. gave to the Dean the keeping of this clock, with 6d. per day, to be received at the Exchequer. About the same time a clock was placed in Canterbury Cathedral. Then we have an authentic account of one of the earliest astronomical clocks, a clock invented by Richard Wallingford, abbot of St. Albans, who, in 1326, had it placed in the monastery. It showed the hours, the apparent motion of the sun, the changes of the moon, the ebb and flow of the tide, etc. In the time of Henry VIII., Leland said, "All Europe could not produce such another." Wallingford's account of this clock is preserved in the Bodleian Library. When the inventor had finished this clock, so scarce was the knowledge of mechanics, that he was obliged to compose a book of directions for managing and keeping the clock in order, lest it should be ruined by the ignorance of the attendants. The old clock in Wells Cathedral (removed from Glastonbury Abbey at the Reformation) was constructed about the year 1320, by Peter Lightfoot, a monk of Glastonbury; the dial showed the motions of the sun, moon, etc. On the top of the clock eight armed knights saluted each other with a rotatory motion.

In 1344, James Dondi, citizen of Padua, philosopher, physician, and astronomer, constructed for his native city a clock similar to Wallingford's; this obtained for him the name of Horologicus, and his family existed at Florence till our time, and bore his name. His son, John Dondi, made another clock for the city of Pavia. About the same time one still more complicated was made for Padua by William Zealander. Clock-making also flourished in Germany, particularly at Nuremberg, about the beginning of the sixteenth century. The middle of the fourteenth century seems to afford the first certain evidence of what would be now called a clock, or regulated horological machine. There is a clock in Dover Castle, dated 1348; and there is in Peterborough Cathedral a clock still in use as to the striking parts, of which the combination is very like that of the Dover Castle clock. It is said that the first clock at Bologna was fixed up in 1358. Henry de Wyck, a German artist, placed a clock in the tower of the palace of Charles V., about 1364; Edward III. gave protection to three Dutch horologiers, who were invited from Delft into England in 1358; and this appears to have been the probable introduction of clockwork into England. The origin of the famous clock in Strasburg Cathedral dates from 1352: the artist's name is unknown, but the clock was a highly successful work of the art of the period. It was divided into three parts—a universal calendar, an astrolabe, and figures of three kings and the Virgin carved in wood. At the striking of each hour the three kings bowed to the Virgin, whilst a carillon played a cheerful tune, and a cock crowed, and flapped its wings. This clock being out of order in 1547, its repair was entrusted to the charge of three mathematicians of high repute: they died before their work was finished, but it was taken up by a pupil of one of them, Count Dasypodius, who completed his task in four years. The clock went well until the year of the great revolution, when it struck for the last time. Nearly fifty years passed, when one Schwilgen, a mathematician of Strasburg, repaired and reinstated the clock, in four years, from June 24th, 1836: its mechanism was placed in the old case, the figures being increased and improved by jointed limbs. The quarter chimes are struck by four figures which move in a circle around a skeleton mower; the hour bell is struck by a figure of an angel turning an hour-glass, through which sand runs. Every day at noon there is a procession of the twelve apostles round a figure of the Saviour; the cock flutters his wings, opens his beak, and crows three times. The clock shows the month, the day of the month, the sign of the zodiac, the Dominical letter, the sidereal time, the Copernican planetary system, and the precession of the equinoxes; and its mechanism marks the 29th day of February in every leap year. The full mechanism is set in motion at noon only. Fortunately, this curious clock was not injured during the destructive siege of Strasburg by the Prussians in 1870, though the cathedral did not escape. Lehmann informs us of a clock at Spires with such mechanism in 1395. Nuremberg had a public clock in 1462. Auxerre had one in 1483, and Venice in 1497. The clock in the north tower of Exeter Cathedral has two dials, and its construction is referred to the reign of Edward III., when the science of astronomy was in its nonage, and the earth was universally regarded as the central point of the universe. The upper disc of this clock, which was added in 1780, shows the minutes. The hour disc is divided into three parts; the figure of the earth forming the nucleus of the innermost circle, that of the sun traversing the outer space, that of the moon the intermediate one. The sun is stamped with a fleur-de-lis, the upper end pointing to the hour of the day, the lower to the age of the moon; while the figure of the moon is made black on one side, and moved by the clockwork, so as to imitate the inconstant original.

In 1382, the Duke of Burgundy ordered to be taken away from the city of Courtray, on the entry of the French army, a clock which struck the hour, and which was the best at that

time known; the Duke had it brought to Dijon, his capital, where it may be seen in the tower of Notre Dame. The cathedral clock at Lyons, dated 1385, was nearly as curious as the above. It resembled in its mechanism the Strasburg clock: two horsemen had a combat on the dial-plate; a door opened and displayed the Virgin Mary with Jesus Christ in her arms; the Magi, or Wise Men with their retinue, presented their gifts, headed by two trumpeters playing. *La Grosse Horloge* at Rouen is chiefly remarkable for its great size. The cathedral clock at Lunden, in Denmark, said to have been constructed in 1390, must have been copied from Lyons cathedral clock; in the dial are seen the year, month, week, day, and hour of every day throughout the year, with the feasts movable and fixed, and motion of the sun and moon; the clock strikes by two horsemen in encounter giving as many blows as the bells sound hours; the Virgin Mary, enthroned, with Christ in her arms, the Magi, etc., as are shown at Lyons. Lubeck cathedral clock, date 1405, represents the changes of the heavenly bodies until 1875; when it strikes twelve, a number of automaton figures are set in motion; the Electors of Germany enter from a small side-door, and inaugurate the Emperor, who is seated upon a throne in front. Another door is then opened, and Christ appears, when, after receiving his benediction, the whole cavalcade retires amidst a flourish of trumpets by a choir of angels. On each side are bas-reliefs of passages in the life of our Saviour; in that of the Last Supper a mouse is peeping from beneath the table-cloth—the *mouse* representing the armorial bearings of the once puissant Lubeck. The similarity of the above clocks has led to the supposition that they were constructed from a design under Papal authority, to cause wonderment in the people.

About 1525 the clock of St. Mary's, Oxford, was furnished out of fines imposed on the students of the University. In the middle or clock quadrangle of Hampton Court Palace, over the principal entrance, is, according to Dr. Derham, the oldest English-made clock extant, constructed in the year 1540, by a maker of the initials "N. O." This clock contains mechanism for representing the motions of some of the heavenly bodies. Copernicus was living at the time of its date, but more than a century elapsed after this time before the invention of the pendulum was applied as the regulator of clocks. These facts render the wheelwork of this ancient clock, and especially its celestial mechanism, very interesting. Dr. Derham, describing it in his "Artificial Clockmaker," 1714, states that the Hampton Court clock shows the time of day, and the motions of the sun and moon, through all the degrees of the zodiac, together with the days of the month, the sun and moon's place in the ecliptic, the moon's southing, etc. Langley Bradley repaired it in 1714, and it was again altered and repaired somewhere between 1760 and 1800. The astronomical furniture is incorrectly attributed to Thomas Tompion, the celebrated clockmaker, but he died in 1669, or about 129 years after its construction, though he might have been employed upon it (see Henderson's "Horology," pp. 16, 18, 2nd edit. 1836). The dial, and part of the wheel attached to the back of the dial, still remain. About the year 1560, the Danish astronomer, Tycho Brahe, possessed four clocks, which indicated the hours, minutes, and seconds; the largest of these had only three wheels; one was about three feet in diameter, and had 1,200 teeth in it, a proof that clockwork was then in a very imperfect state. In 1577, Moestlin had a clock so constructed as to make just 2,528 beats in an hour, 146 of which were counted during the sun's passage over a meridian or azimuth line, and thereby determined his diameter to be 34′ 13″; so the science of astronomy began thus early to be promoted by clockwork; and astronomy, in its turn, gave rise to some of the most essential improvements in clockmaking. Martinelli, in his work printed at Venice, 1663, describes an old clock going in his time in the Grand Piazza, in which two Moors struck the hour upon a bell, three kings entered from a door, and after making obeisance to figures of the Virgin and Child, placed in a niche, retired through a door on the opposite side. John Evelyn relates that about the middle of the seventeenth century, a man was killed by this famous clock: "While repairing the works, he stooped his head in such a position, and in such a nick of time, that the quarter boy struck it with his hammer, and knocked him over the battlements."

In the palace of Versailles are two curious clocks, one being the clock of the king's death, in the *Cour de Marbre*. This clock has no mechanism, and has only one hand, which is placed at the precise moment of the death of the last king of France, and is not moved during the whole of his successor's reign. This custom dates from the time of Louis XIII. In the saloon of Mercury is a clock dated 1706; each time that it strikes, two cocks flap their wings, small doors open, and two figures advance, holding bucklers, on which Cupids strike the quarters; a figure of Louis XIV. steps forth, and from a cloud, Victory descends and places a crown on the king's head; the puppets all disappear, and the hour strikes. A story told of Louis XI. (King of France from 1461 to 1483) shows that horology had then made great advances. A gentleman who had lost a great deal at play, stole a clock belonging to the king, and hid it in his sleeve; in a short time, the clock, which continued to go, notwithstanding its removal, struck the hour, and the theft, of course, was discovered. Louis, as capricious in kindness as in tyranny, not only pardoned the culprit, but made him a present of the clock. It was customary formerly, in several French towns, to make clocks tell the hour by means of one or more statues, which struck the bell with hammers. A similar custom prevails in Italy. In the little town of Lambex, there is on the top of a tower the figure of a man who strikes the hour in this manner; at the same instant, a woman appears, and makes him a low curtsey, and then walks once round him. Portable clockwork exhibitions of sceneries, the life and death of our Saviour and the Blessed Virgin, and models of Nazareth, Jerusalem, and Mount Calvary, are among the attractions of French fêtes. Invention was, for a time, limited to enriching clocks by the addition of moving figures, processions of saints, with the Virgin, representations of mysteries and pious subjects; while others were made by the more learned to represent the motions of the heavenly bodies. Of this class were the two "wooden horologists" of St. Dunstan's, Fleet Street, which struck the quarters upon a suspended bell, each moving his head at the same time. These figures of savages, life size, carved in wood, stood beneath a pediment, each having in his right hand a club, with which he struck the bell. When the church was taken down, in 1830, they were purchased, with the bells, for £200, by the Marquis of Hertford, for his villa in Regent's Park. There is a like contrivance to the above in Norwich Cathedral; and a general name for these figures was "Jacks of the Clockhouse."

TECHNICAL DRAWING.—XI.

DRAWING FOR CARPENTERS AND BUILDERS.

DEVELOPMENT OF THE SURFACES OF ROOFS.

ALTHOUGH the whole subject of the development of prisms is treated in lessons on "Projection," it is deemed desirable to give two examples here, showing the immediate application of the principles to roofs, in order to enable the student to find the exact shapes of the surfaces of which they are composed; and, as in the case of a hipped roof, the length of the hip-rafters.

Fig. 82.—In this figure, $a\,b\,c\,d$ is the plan of the building to be covered with a hipped roof.

To draw the plan of the roof, bisect the angles of the parallelogram, and the bisecting lines meeting in e and f will form the plans of the hip-lines, and the line joining e and f will be the plan of the ridge.

It is now required to project the elevation from this plan. To do this, draw any horizontal line, as A B (Fig. 83), and the perpendiculars from c, e, f, d, cutting A B in g, h, i, j, and produce h and i indefinitely.

Produce the perpendicular at e until it reaches l; then it will be clear that $k\,l$ is the width of the roof-trusses (at $k\,l$ and $m\,n$), which would be at right angles to the sides $a\,b$ and $c\,d$.

Draw $k'\,l'$ (Fig. 84) equal to $k\,l$ in Fig. 82, and at the middle point, o, draw the perpendicular, $o\,p$, equal to the *real* height of the truss, which is, of course, a matter dependent on the design of the architect. This triangle, then, will be the shape of the truss at this point, and is the section *across* the roof.

Make $h\,q$ and $i\,r$ in Fig. 83 equal to $o\,p$ in Fig. 84; draw $g\,q$, $q\,r$, and $r\,j$, which will complete the elevation; and this will also be the longitudinal section through the ridge.

We now have to find the real length of the hip: to do this

draw $f\,s$ (Fig. 82) equal to $o\,p$ (Fig. 84), and at right angles to $f\,d$; join $d\,s$; then the right-angled triangle $d\ f\ s$ is the true shape of the hip-truss. This will be understood by cutting a piece of cardboard of this shape, and placing it on its edge on $d\,f$, then it will be seen that $d\ s$ will be the length of the hip.

To develop the covering of this roof:—It will, of course, be understood that this will consist of four planes, which will meet at the hip-lines. Now, it has already been shown that the ends are triangles, of which $a\ e\ c$ and $b\ f\ d$ are the plans; the length of lines $a\ c$ and $b\ d$ remains unaltered, but the *real* length of $c\,e$, $a\,e$, $b\,f$, and $d\,f$ has been proved to be $d\ s$; therefore on $d\ b$ and $a\ c$ construct isosceles triangles, having $d\ s$ for the two remaining sides; these triangles then, $a\ t\ c$ and $b\ u\ d$, are the true shape of the coverings of the ends of the roof.

Now from c and d, with radius $c\ t$, describe arcs cutting the perpendiculars k and m in v and w; join $d\,w$, $v\,c$, and $w\ v$; then the trapezoid $c\ v\ w\ d$ is the development of one of the planes forming the side of the roof-covering. The same length set off on the perpendiculars l, n will give the points x, y, which will complete the fourth plane.

We will now proceed to find the form of the hip when the roof is a groined one.

Fig. 83.

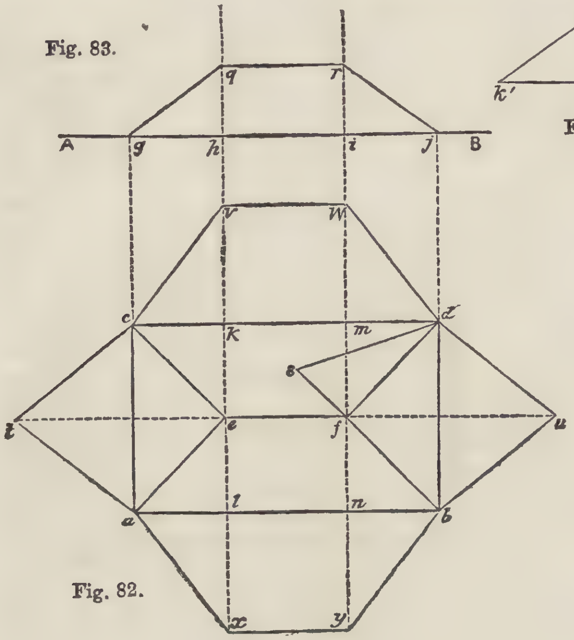


Fig. 82.

Fig. 84.

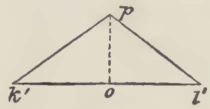
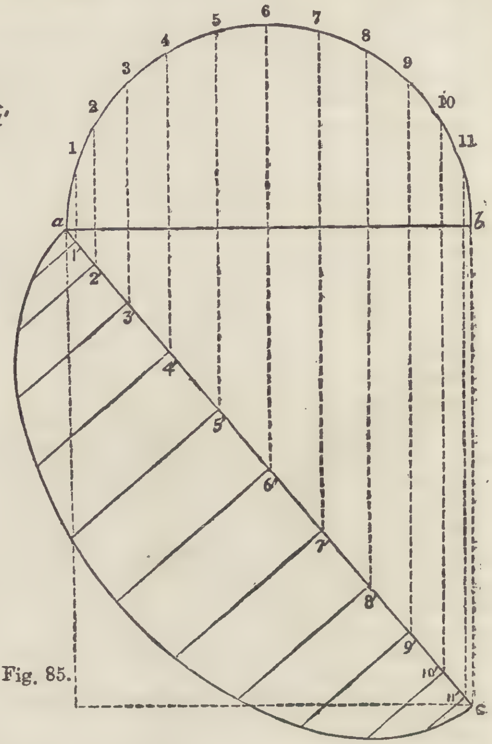


Fig. 85.

Fig. 86.



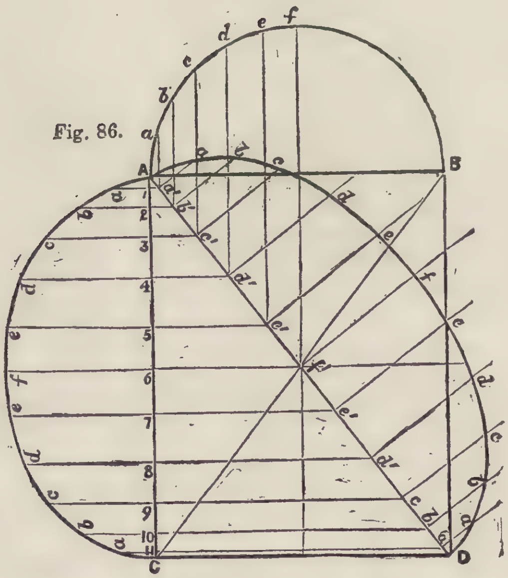
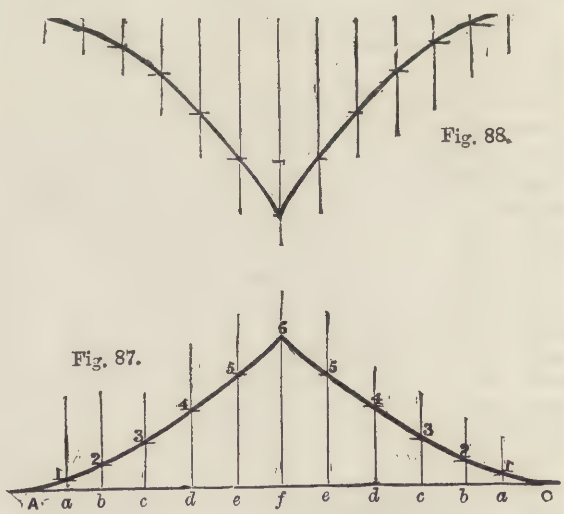


Fig. 88.

Fig. 87.



Let me ask you to imagine yourself standing on the platform of a railway at the side of a semi-circular arch by which a road is carried over it; you will then see that whilst the face or elevation of the arch where it crosses the railway at right angles is semi-circular, its span being of course the diameter of the circle of which it is the half, the length from the springing near which you are standing, to the most distant springing (that is, the one on the opposite side of the line at the other end of the arch) will be much longer; yet the arch there *is not any higher*, although its span thus taken crosswise is longer,

because the diagonal of a square or other rectangle is longer than either of its sides. The principle on which to find the shape of the curve which would reach from the springing at which you are standing to the one referred to, is also shown in Fig. 85.

On a b describe a semicircle, and divide it into any number of equal parts in the points 1, 2, 3, 4, etc. From these points let fall perpendiculars on a b, and produce them downwards till they cut the diagonal a c in the points 1′, 2′, 3′, 4′, etc. Now, from the points where the lines 1′, 2′, 3′, 4′, etc., cut a c, draw lines perpendicular to a c; make each of these equal in height to those correspondingly lettered in the semicircle, and the curve drawn through their extremities will be the form required.

Fig. 86.—Here A B C D is the plan of a building to be covered by a groined roof.

The arch, the springing of which is A C and B D, is a semi-cylinder.

The arch which has its springing in A B and C D, being of the *same height* but of wider span, is a semi-*cylindroid*.

A cylindroid is a solid body of the character of a cylinder. But whilst in a cylinder all sections taken at right angles to the axis are circles, in the cylindroid all such sections are *ellipses*. It is, in fact, a flattened cylinder.

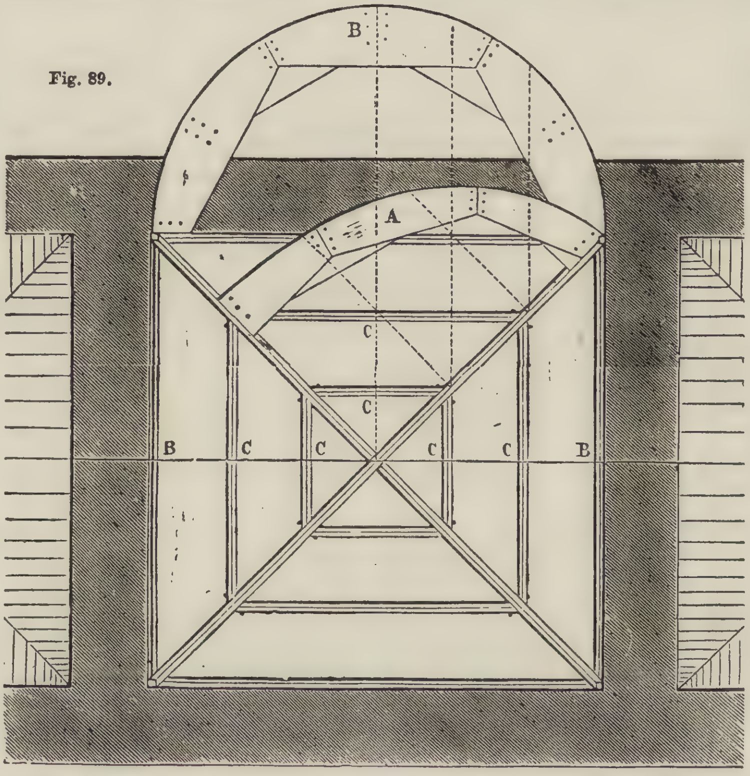
The curve at the groin, then, is generated by the penetration of a cylindroid and cylinder.

On A B describe the semicircle which represents the form of the arch at the ends A B and C D, and divide it into any number of equal parts, a, b, c, etc. It is only necessary to use the quadrant, as throughout the working the measurements are the same on each side.

Draw the diagonals A D and B C.

From a, b, c, d, e, f draw lines perpendicular to A B, and cutting the diagonal A D in a', b', c', d', e', f', and set off the same distances on the other half of the diagonal.

Fig. 89.



From these points draw lines at right angles to A C, and passing through it in points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11; mark off on the perpendicular 6 the height of 6 f equal to the height of the semicircle f, and on the perpendiculars 5, 4, 3, 2, 1 mark off in succession the heights of the perpendiculars e, d, f, c, b, a, as contained between the semicircle and the *diameter*. Set off the same heights on the corresponding perpendiculars on the other side of 6 f, and the curve traced through these points will be a semi-ellipse, which is the section of the semi-cylindroid forming the arch of which A B and C D are the springings.

We now proceed to find the curve of the groin; and it will be evident that, although the span is still further increased in length, the heights of the different points in the curve will be the same as in both the previous elevations.

The span, then, of the arch at the groin is the diagonal A D (or B C), to which the divisions a', b', c', d', e', f' have already been transferred from the semicircle, and from these the lines were carried at right angles to A C, on which the heights of the points in the curve were set off.

These points on the diagonal, then, will be seen to be common to both arches, since they are the plans of the points in the roof where the cylindrical and cylindroidal bodies penetrate each other. At these points, therefore, draw lines perpendicular to the *diagonal*, and mark off on these the heights of the perpendiculars in the semicircle from which the points on which they stand were deduced. These extremities being connected, the curve so traced is the groin curve, and will give the shape for the centering for the groin, as the semi-circle and semi-ellipse will for those used in the elevations of the arches.

It now only remains to develop the soffits or under surfaces.

Fig. 87.—Draw any straight line, and commencing at A set off on it the distances into which the curve A C is divided (measuring on the *curve*, *not* on the springing-line), namely, the distances A a, a, b b, c c, etc.

At the points on the straight line thus marked, draw perpendiculars; make the middle one equal to 6 f, those on e, e equal to 5 e, those on d, d equal to 4 d, those on c, c equal to 3 c, those on b, b to 2 b, and these on a, a equal to 1 a. Join the extremities of these perpendiculars, and the two curves meeting in a point, and joined by the original straight line, will form the development of the soffit of the cylindroidal arch.

Fig. 88 is the development of the semi-cylindrical arch. As this is worked in precisely the same manner from the *semicircle*, no further instructions are deemed necessary.

Fig. 89 is the plan of a building to be covered by a roof of a pyramidical form, the hips, however, being *curved* instead of straight, so that the roof is really a square dome.

Now in this case, the given rib crossing from B to B, and that which would cross it at right angles through the centre, is shown at B, which is the form of wooden centering which would be used to divide the semicircle into any number of equal parts. Draw diagonals in the square, and from the divisions in the semicircle draw lines perpendicular to the diameter, and cutting the diagonal; at these points erect perpendiculars, and make them equal to those in the semicircle; then the curve drawn through their extremities will be the shape of the hip. This is shown lying down in the illustration, and the student is advised to cut the form in cardboard, when by standing it on its edge against a semicircle placed on the line B B, he will be able thoroughly to comprehend the difference between the forms caused by their positions.

When a roof is constructed as in this figure, but the curve is truncated, or cut short by a flat surface, it is called "coved and flat."

Ceilings are sometimes built in this manner. They form a sort of compromise between a flat ceiling and the various arched forms practised by the ancients. They do not require so much height as the latter mode, and have therefore been of considerable use in the finishing of modern apartments; but although the form is admired by many, it naturally is wanting in the elegance and grandeur of entire arched ceilings, nor does it admit of that beauty of decoration of which they are susceptible.

AGRICULTURAL CHEMISTRY.—IV.

BY CHARLES A. CAMERON, M.D., PH.D.,

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CHAPTER IV.—FORMATION AND COMPOSITION OF SOILS.

The solid "crust" of the globe is composed of substances termed *rocks* by the geologist, whether they exist in the enormous compact masses popularly known as *rocks*, or in the slightly coherent states called clay, gravel, sand, etc. Granite, gneiss, trap, basalt, sandstones, limestone, and various other minerals, constitute the solid rocks. They are composed of the metals potassium, sodium, magnesium, calcium, aluminum, and iron, united with the metalloids (non-metals) oxygen, carbon, silicon, sulphur, and phosphorus. The metal manganese occurs also (and very commonly) in rocks, but only in small quantities; and the metals barium and strontium are also occasionally found in masses of rock. Fluorine combined with calcium (fluoride of calcium, or fluor spar) is also met with in rocks, but in comparatively minute quantities. The great bulk of rocks is made up of the elementary substances silicon, oxygen, carbon, aluminum, and calcium.

Silica, or silicic acid, is composed of 46·7 parts of silicon combined with 53·3 parts of oxygen. It constitutes the great bulk of most kinds of rock, such as granite, gneiss, and basalt, and it is the chief constituent of such common minerals as felspar, mica, hornblende, and meerschaum. Quartz, flint, rock crystal, jasper, chalcedony, and agate are varieties of silica.

Aluminum is a white, malleable metal, about one-third the weight of silver. It is but very slightly affected by the air. 53·39 parts of this metal combined with 46·61 parts of oxygen constitute the earth alumina. The latter, when artificially prepared, is a white substance, insoluble in water, but possessed of a great tendency to combine with that liquid. The intensely hard mineral corundum is pure alumina; and emery, and the beautiful gems termed the sapphire and the ruby, are slightly impure varieties of this earth. The plastic constituent of clays and porcelain earths is alumina; and this body is the basis of bricks and pottery. The affinity which alumina has for moisture may easily be proved by applying the tongue to a brick or piece of unglazed porcelain.

The metal calcium, united with oxygen in the proportion of 71·43 parts of the former with 28·57 parts of the latter, constitutes the earth lime, or calcic oxide. This body is white, and is about three times the weight of water. When water is poured upon lime, they combine, the earth swells up, and (unless there be too much water) crumbles into a fine powder. During this process a large amount of heat is evolved. This compound of water and lime is termed *slaked lime*, or calcic hydrate (formerly, hydrate of lime), and is largely employed as an ingredient of mortars and cements. Limestone and marble are essentially composed of lime, or calcium in union with carbonic dioxide. When either mineral is highly heated, carbonic dioxide is expelled, and calcic oxide (quick or burnt lime) remains. The important earthy salt gypsum, or plaster of Paris, is calcic sulphate; and tricalcic diphosphate is one of the most valuable earthy compounds used in agriculture. A large number of minerals containing tricalcic diphosphate exist, and are employed for agricultural purposes.

The metal magnesium occurs far less abundantly than calcium. 60·28 parts of this metal and 39·72 parts of oxygen form the earth magnesia—a bulky, white, tasteless powder. Dolomite is a compound of calcic carbonate and magnesic carbonate, and the well-known Epsom salts are magnesic sulphate. Magnesium occurs in all fertile soils, and in a great variety of minerals, such as, for example, chrysolite, French chalk or steatite, meerschaum, serpentine, and asbestos.

Geologists have not been able to penetrate very far beneath the surface of the earth; consequently, the composition of all but the mere skin, so to speak, of our globe is unknown to us. So far as we have penetrated, certain kinds of rocks have been found in layers or beds termed *strata*, overlying each other in regular succession. Occasionally the strata have a horizontal direction, but more frequently they form angles with the surface of the earth.

The stratified* rocks are termed *aqueous*, because it is believed that they have been formed out of older rocks by the action of water. The hardest kinds of rock crumble away under atmospheric influences, and the *débris* or fragments become transported to considerable distances by means of drainage water, rivulets, rivers, the sea, and even by glaciers and icebergs. The pulverised particles of rock deposited in various places out of water undergo a kind of cementation and form new rocks. The latter, being produced from a gradually-deposited sediment, necessarily have a stratified or leaf-like structure. Some stratified rocks are derived from the remains of animals. Chalk and limestone are composed chiefly of the remains of shell-fish and other animals. So great is the rock-forming power of large rivers that, according to Sir Charles Lyell, the Nile annually deposits 3,702,758,400 cubic feet of solid earthy matter beneath the waters of the Mediterranean. The greater part of Egypt was believed by Herodotus to be "the gift of the Nile."

The rocks termed *igneous* are those which have been subjected to, or formed under the influence of, intense heat. They are generally composed of small crystals or vitreous (glass or slag-like) substances. They generally underlie the stratified rocks, but often pass up through the latter in a wedge-like form. Granite and trap are igneous rocks, and lava, or other volcanic rock, also belong to this group, and are the latest members of it. Limestone, oolite, and sandstones are familiar examples of stratified rocks. Rocks intermediate between aqueous and primary rocks are termed *metamorphic*: gneiss is a metamorphic rock. Fig. VII. shows the appearance presented by a vertical section of stratified rocks.

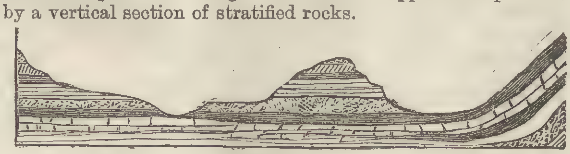


Fig. VII.

The greater portion of the surface of the "dry land" is covered with loose fragments of rocks, mixed with the remains, more or less altered, of plants and animals. These matters are termed *soils*, and they extend downwards to distances varying from an inch to more than twenty feet. There are two kinds of soil, the *super* and the *sub*. The former term is confined to the layer next the surface, which contains nearly all the organic matter (*i.e.*, animal and vegetable substances), and throughout which the roots of plants ramify. The sub-soil generally closely resembles the super-soil so far as their mineral ingredients are concerned, but the condition in which these ingredients exist is somewhat different in the two soils.

Both super- and sub-soils are often formed by the disintegration of the hard rocks underlying them; but sometimes they are produced from the *débris* of rocks transported by aqueous agency from distances more or less considerable.

The agencies which form soils are frost, rain, damp, oxygen, and carbonic dioxide. Water, when it is converted into ice, expands about 10 per cent. of its volume. In the densest rocks there are little cavities containing water, which in winter often expand with irresistible force into ice, and thereby increase the size of the cavity. This process, carried on for centuries, produces the disintegration of enormous quantities of rock. The mere mechanical action of rain and hail upon rocks also crumbles away in process of time the densest stone surfaces—witness the rough and decayed aspect presented by so many of our stone buildings. Carbonic dioxide has a great affinity for potassium and sodium; and as these metals are common ingredients of rocks, they are often abstracted from them by the free carbonic dioxide of the atmosphere—a circumstance which renders the rocks more porous and friable. The ferrous oxide (protoxide of iron) in rocks is often converted into ferric oxide (per- or sesqui-oxide) by the atmospheric oxygen, and this process tends to break up the structure of the rock. The influences of air and moisture upon the solid crust of the globe are, of course, confined to the surface, and take place with an extreme degree of slowness; but influences, however small, exerted during a considerable period of time, ultimately produce great effects. The stratified rocks (which include soils) now in existence have been produced by the atmospheric influences of countless ages. It is, indeed, probable that, as Liebig remarks, the atmospheric influences of a

* From the Latin *stratum*, a layer, and *facere*, to make.

thousand years are necessary to form from any kind of rock a layer of arable soil one-twelfth of an inch thick, suitable for the growth of plants.

The composition of soils varies greatly. Some contain considerable amounts of calcic carbonate, others are very rich in organic matter, whilst many are composed of but little more than silica. As a rule, silica is by far the most abundant mineral ingredient of soils; next comes alumina; and ferric oxide and calcic carbonate are about equally abundant. The following is the composition, according to Voelcker, of a sandy soil (Tubney Warren, Abingdon), deficient in lime, alkalies, and phosphoric acid. 100 parts of the dried soil contain—

Organic matter	5·88
Oxides of iron, and alumina	4·11
Carbonate of lime (calcic carbonate)	0·62
Magnesia	0·22
Potash and soda	0·14
Phosphoric acid	0·07
Sulphuric acid	0·04
Insoluble silicious matter (fine sand)	88·92
	100·00

The amount of silica is generally from 80 to 94 per cent. in sandy soils, from 70 to 80 in clay lands, from 60 to 70 in loams and rich moulds, from 40 to 60 in marly clays, from 5 to 40 in calcareous or limy soils, and in marls.

The proportion of alumina is greatest in rich loams, but it rarely exceeds 15 per cent. In clay soils alumina exists on the average to the extent of about 7 per cent.; in sandy soils its per-centage varies from 1 to 5. Marls, calcareous soils, and vegetable moulds contain from 1 to 8 per cent. of alumina. The larger the proportion of alumina in the soil, the more difficult is its cultivation—the adhesive character of the earth offering a stubborn resistance to the passage of the plough and the spade through it. Porcelain and brick clays contain from 30 to 40 per cent. of alumina.

The per-centage of calcic carbonate varies from 90 per cent. in the case of marls and limestone soils to mere traces. Clays and loams generally contain from 1 to 3 per cent. of this substance. Less than 1 per cent. may be regarded as a defective proportion.

Potash exists in soil from the merest trace to nearly 3 per cent. Soils rich in alumina are, with rare exceptions, also rich in potash. Sandy and peaty soils and marls are in general deficient in this alkali.

Soda is not so important a constituent of plants as potash; and, except near the coast, it is not quite so abundant in soils as potash. Its proportion varies from a trace to 2 per cent.

Magnesia is found in all fertile soils, and in per-centages which range from ·05 to 1·5.

Marly, peaty, and calcareous soils contain very minute amounts of phosphoric acid, but in clays its per-centage is occasionally 1·5. In general, even very fertile land contains less than 1 per cent., and the average amount is probably about 0·4 per cent.

Sulphuric acid and chlorine occur very sparingly in soils. Carbonic dioxide is abundant in all cases where there is much lime. It is generally found in the form of calcic carbonate and magnesic carbonate.

Organic matter (animal and vegetable substances more or less decomposed) is present in all soils capable of producing good crops. Sometimes, as in the case of bogs and peaty mosses, it is too abundant. It is most deficient in sandy soils, which often contain less than 1 per cent. of this ingredient. Cold clays are in general poor in organic matter. Fertile loams include from 10 to 14 per cent. of this valuable element of fertility.

BUILDING CONSTRUCTION.—VI.

BRICKWORK (*continued*).

FOUNDATIONS.

Having in the previous lesson shown the difference between English and Flemish bonds, we now purpose illustrating the method by which these may be worked together.

Figs. 30 and 31 show plans of first and second courses of a wall in which the front is built in Flemish and the back in English bond. This is considered a good wall, but still possesses the disadvantage of half-bricks. And thus it will be seen that in the one course the front line of bricks, and in the other the back line, is totally unattached to the rest; whilst in Figs. 28 and 29 the headers penetrate two-thirds into the thickness of the wall.

Flemish bond has been much used in situations where the walls were not to be covered with stucco, for the reason already assigned, viz., its neat appearance. But in every case where the greatest strength and compactness are required the English bond is preferred, in consequence of its admitting of more transverse bonding than the other. Flemish bond was introduced into this country in the time of William and Mary; but why it has received the name it bears does not seem to be known; for in Flanders, Holland, Rhenish Germany, etc., this system is not by any means generally practised, the style which we call old English bond being almost universally adopted.

A third kind of bond is sometimes used with the view of strengthening very thick walls. This mode consists in laying the bricks which fill up the core, or space between the front and back surfaces, diagonally or angle-wise, their direction being reversed in each course. This is called a *rake*, and does away with the necessity for using half-bricks in the heading courses; but, of course, it leaves triangular interstices at the points where the angles of the bricks in the core meet the straight faces of the external facings of the wall.

Fig. 32 represents the plan of a three-brick wall built in this manner. It will be seen that the connection between the faces and the core is but very imperfect. The external faces consist of alternate courses of headers and stretchers, the core being filled up by a raking course. This course rests on, and is also covered by, a complete course of headers, and each time it occurs the direction of the bricks is reversed.

Fig. 33 is the plan of a wall similarly constructed, called *herring-bone* bond. In this mode also, courses of headers would bed and cover the herring-boning, and the direction of the bricks in the core, like in the last, is reversed in each course. It will be noticed that this plan leaves a central line of squares to be filled up by half-bricks, in addition to the triangular pieces used at the sides.

Neither of these two systems should be used for any but very thick walls.

Perfect accuracy in bricklaying, as indeed in all mechanical arts, cannot be too much impressed on the artisan; and this should be carried out not only in the parts of a structure which are visible, but in those which may be hidden. For instance, it is of the utmost importance that all the joints in brickwork should be perfectly plumb or vertical, and that every course should be absolutely horizontal, both lengthwise and across. The *lowest* courses of a brick wall should be laid with the strictest attention to this particular; for, as all the bricks are of the same thickness, any irregularity will be carried up throughout the whole wall, and the workman will then attempt to rectify it, or to "level it up," by using more mortar in some parts than others; but, of course, mortar whilst wet is to a certain extent compressible where bricks are not, and there will thus be unequal settlement, which will subsequently not only impair the appearance, but endanger the safety of the wall, and possibly of the entire structure. In order to save the trouble of constantly applying his rule and level to the work, the bricklayer, when he has got beyond the footings or foundations, builds up three or four courses at the ends of the wall, as at A and B (Fig. 34). These he very carefully plumbs and levels across; he then strains a line from one end to the other, and this guides him as to the level of his course; but if the distance be long, the line will sag or hang slightly downward in the middle, and to prevent this, occasional bricks are placed which serve to support it, as shown at C. When the work has been carried up three or four courses, it should, however, be tested with the plumb-rule and level. In bricklaying, the workman spreads the mortar over the last course with his trowel, so as to form a bed on which the brick may rest. As any mortar spreads beyond the edge of the course, it is caught up on the face of the trowel, and is put up against the vertical end of the last brick laid in the new course. The bricklayer then with his left hand *lays* the brick, and presses it downwards until it is in its exact place in the line, sometimes striking it with the side of the trowel, or giving it a smart tap with the end of the handle. The small quantity of mortar thus pressed out between the

bricks is knocked off with the trowel, and the line smoothened with the point—that is, if it is to be seen; but on the inside of walls which are to be plastered, the rough projecting line of mortar is left, as it helps in attaching the plaster. It is advisable that bricks should be damp when they are being laid; for if their pores are full of air, and their surfaces covered with dry dust, the mortar will not adhere. This is generally done on the scaffold, for wetting them below would make them much heavier for the labourer to carry up, and many of them would each other; and no space between them should be left unoccupied by mortar, which may produce adhesion. When the bricks are a fraction under 2½ inches thick, no four courses of bricks and mortar, or brickwork, should exceed 11 inches in height; and if they are fully that thickness, four courses should not reach 11½ inches. The result of thick beds of mortar between the bricks, is that the mortar is pressed out after the joint is drawn on the outside of the front, and being made *convex* instead of slightly *concave*, the joints catch every drop of

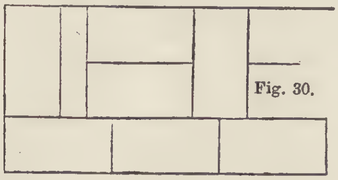


Fig. 30.

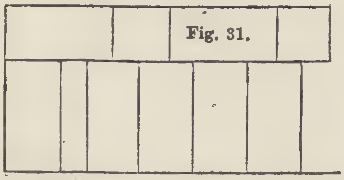


Fig. 31.

Fig. 36.

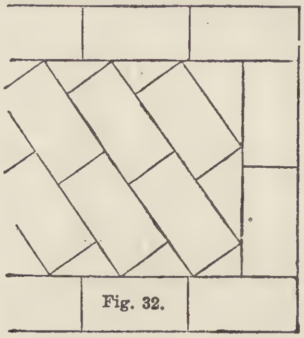



Fig. 32.

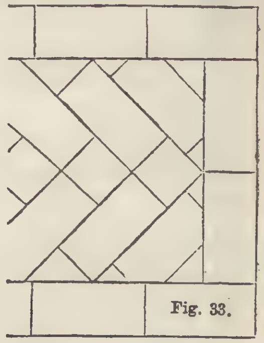


Fig. 33.

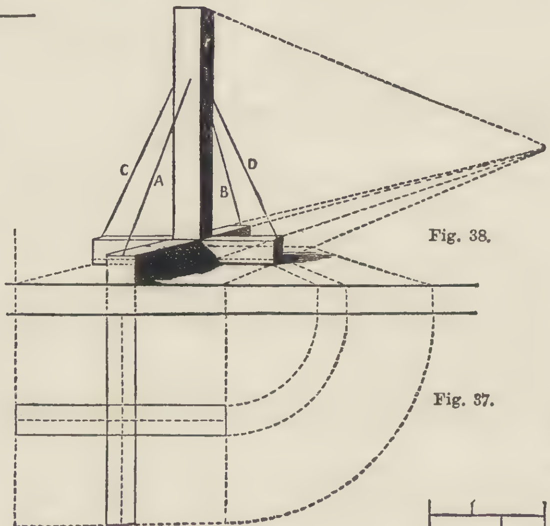


Fig. 38.
Fig. 37.

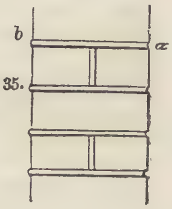
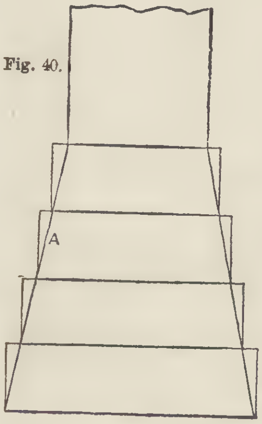


Fig. 35.

Fig. 40.


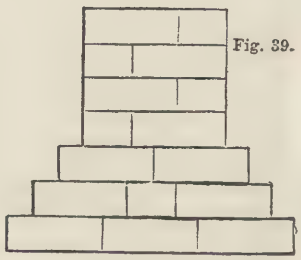


Fig. 39.

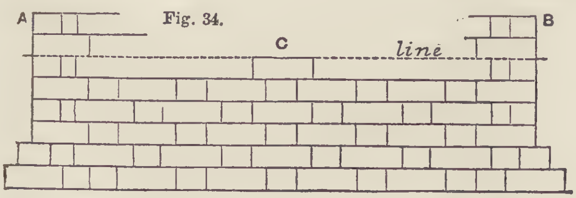


Fig. 34.

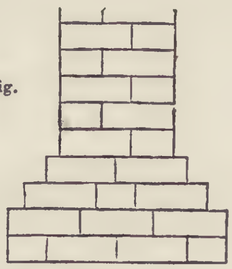
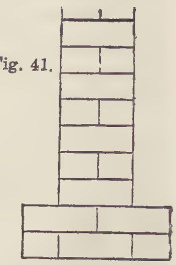
Fig.


Fig. 41.


dry before wanted for use. They should, therefore, be dipped in water just as they are wanted, and this may be done by boys supplying them as required by the bricklayer.

The following remarks, taken from Mr. W. Hoskings' excellent work, are quoted, as from their exceedingly practical character they cannot fail to be of use to the artisan:—"As mortar is a more yielding material used in bricklaying for the purpose of making the detached portions of the staple adhere, by filling up their interstices and producing exhaustation—and the object being to produce as unyielding and consistent a mass as possible—as much of it should be used as is sufficient to produce the desired effect, and no more. No two bricks should be allowed to touch, because of their inaptitude to adhere to rain that may trickle down the face of the wall, and thus become saturated; the moisture freezes, and in thawing bursts the mortar, which crumbles away, and creates the necessity, which is constantly recurring, of 'pointing' the joints to preserve the wall." Fig. 35 shows the section of a 9-inch wall with the joints on the side *a* as drawn, and on the side *b* as bulged out in consequence of the quantity of mortar in them yielding to the weight above. This, too, is in addition to the inconvenient settling which is the consequence of using too much mortar in the beds. In practice, bricklayers lay the mortar on the course last finished, and spread it over the surface with the trowel, without considering or caring that they have put no mortar *between* the bricks of that course—except

in the external edges of the outside joints. As the mortar is not, or ought not to be, so thin as to fall into the joints by its own weight, unless they press it down, half the space between the bricks remains in every case unoccupied; and the wall is consequently hollow, incompact, and necessarily imperfect. To obviate this it is common to have thick walls "grouted" in every course—that is, mortar made liquid, and called *grout*, is poured on, and spread over the surface of the work, that it may run in and fill up the joints completely. This, at the best, is but doing with grout what should be done with mortar; and the difference between the two consisting merely in the quantity of water they contain, mortar must be considered the best; for the tendency of grout is, by hydrostatic pressure, to burst the wall in which it is employed; and moreover, it must, by taking a much longer time to dry and shrink than the mortar of the beds and external joints, make and keep the whole mass unstable, and tend to injure rather than to benefit it. Filling, or flushing-up every course with mortar, is therefore far preferable, and may be done with very little additional exertion on the part of the workman.

So much having been said on the subject of settlement, it will be seen that owing to stones or bricks being united to each other by mortar, a certain amount of shrinking or settlement from this and other sources is certain to take place. The art of the builder must, however, be devoted to ensure *equal* settlement, and this can only be done, firstly by using the same thickness of mortar throughout, and secondly, by carrying up all the walls which are to sustain the same floor *simultaneously;* for, as all walls shrink immediately after building, the part which is first built will settle before the adjoining part is brought up to it, and the shrinking of the latter will cause the two parts to separate. The ends of the walls first built should be "racked back;" that is, left off slantingly as in Fig. 23, not merely "toothed" vertically as in Fig. 16.

Having thus explained the elementary principles of masonry and bricklaying, the subject of foundations can be proceeded with.

In foundations then, considered in relation to the walls, etc., of buildings, it is necessary to observe:—

1. That when the wind blows, or any other lateral force acts against a wall, etc., the higher it is the more powerful will be the leverage by which it acts against the point on which it rests, and the greater the danger of its being thrown over.

2. The narrower the base on which it rests, the more is it liable not only to be thrown over but to sink.

A timber construction will, perhaps, best serve to illustrate this.

Let Fig. 36 represent a stick of timber or square pole simply placed in the ground; it will be clear that it would be very liable to sink, or that the wind or any other force would be very likely to throw it down. We will endeavour to treat each of these evils separately; and as these lessons aim at not only teaching *work*, but *thought*, let us earnestly impress on our young students the benefit arising from systematic thinking and action, and urge them, before putting pencil to paper, or laying a single brick, to ask themselves: What do I want to do? what is the object to be accomplished? what is the best method of attaining this end? are the means I am taking the best, just because others use them? and if they *are* so, *why* are they so? These questions lie at the foundation of all progress and improvement; and it is through the habit of thus reflecting that an artisan rises above the level of a *working machine* to the dignity of a *working man.*

Let us see, then, what would be the best way to prevent the sinking of the pole, and it will at once be evident that this will be the best accomplished by widening the base. Of course this would be done by placing it on another stick of timber laid horizontally, but better still if two such pieces are placed in the form of a cross (Fig. 37); by this means a basis is formed which, to all intents and purposes, is equal to the complete square in which the cross could be inscribed, and therefore the pole rests, as it were, on a foundation equal to that area. Thus the sinking would be prevented. And now we can turn our attention to the second point, viz., the swaying of the pole, or the liability to be thrown over by any lateral (or side) force. This may be accomplished by mortising struts A, B, C, and D (Fig. 38) into it, and into the stand, in the direction of the single lines here given, and by this means the effect of the breadth of the base will be transmitted to the post. These struts will not only serve to steady the pole, but to relieve the pressure which would otherwise fall on its lower end, but which is thus shared by all the struts, and is by them spread over the whole base; and so fracture at the point where the whole weight would fall is avoided. This illustration has been worked by perspective, a study which will be treated of in other lessons.

In stone and brick walls, the foundations are formed by commencing the lower course wider than the intended thickness of the wall, and then gradually diminishing the breadth until the real size is reached. These projecting edges are called "footings" (Fig. 39).

In stone walls, where the weight falling on the foundation is very heavy, care must be taken that the offsets for footings are not too great in each course, as, owing to the natural brittleness of stone, fracture is likely to ensue; nor should the joints between the stones fall too near or beyond the face of the wall, as in that case they would be liable to yield under the superincumbent weight.

In cases such as the foundations of the piers of bridges, vaults, and other similar constructions, the offsets are made very narrow, and even these are generally slanted off so as to give the wall or pier what is called a "batter," as represented at A (Fig. 40).

In placing the footings in brick walls, the greatest care must be taken to throw the joints as far back within the surface of the wall as possible. Excepting in walls of one-brick thickness, no course of footings should project more than a quarter-brick beyond the one above it; and additional strength is given by a double course below, which, indeed, should be adopted for every thickness of wall.

Figs. 41 and 42 are sections of walls of different thicknesses.

ANIMAL COMMERCIAL PRODUCTS.—VII.

VII.—HAIR AND BRISTLES.

HAIR, the covering of mammiferous animals, consists of slender, elongated, horny filaments, secreted by a conical gland or bulb, and a capsule, which is situated in the mesh-work of the chorion, or true skin. Bristles, hedgehog spines, and porcupine quills, are all modifications of hair, having the same chemical composition, mode of formation, and general structure. Some kinds of hair are perennial, growing continuously by a persistent activity of the bulb and capsule, as human hair, and that of the mane and tail of the horse; other kinds are annual, the coat being shed at certain seasons of the year, as the ordinary hair of the horse, cow, and deer. Hair, of all animal products, is one the least liable to spontaneous chemical change, and in its various forms is valuable as material for numerous branches of industry.

Human Hair.—This is imported from Germany and France, and is furnished, the light-coloured by the German and the dark-coloured by the French girls, who look forward anxiously to the hair harvest for the means of purchasing trinkets and dresses. A head of hair weighs from eight to twelve ounces, and, according to its colour, is worth from thirty to sixty shillings per pound. In the spring, the Paris hair merchants send agents to all parts of France to purchase the beautiful tresses of the French girls, who cultivate an annual crop for sale with the same care as the farmer cultivates a field crop. About 200,000 lb. are purchased in this way every spring, and made into perukes, false curls, etc. Human hair is also manufactured into a variety of articles of personal adornment known in commerce as hair jewellery, such as bracelets, armlets, lockets, brooches, necklace-rings, watch-rings, which are not unfrequently worn in memory of the person to whom the hair belonged.

Horsehair.—This is collected in the various towns of England from ostlers and others, and sent up to London in sacks. Besides that supplied by our own horses, we import annually from Russia and South America about 30,000 cwt. Horsehair is extensively used for military accoutrements, and as stuffing for mattresses; a cloth of great durability is manufactured from it, and employed in covering sofas, chair bottoms, and railway carriages. The first crinoline petticoats were made from horsehair, and hence the origin of the name (Latin, *crinum*, hair).

The hair of the elk, ox, goat, and camel is also extensively imported into this country, and used for various purposes. The hair pencils used by artists, and termed camel's hair pencils, are composed of the fine hairs furnished by the sable, miniver, marten, badger, and polecat, as well as by the camel. They are usually mounted when small in quills, and when larger in tinned iron tubes. A good hair pencil is known by forming a fine point when moistened and drawn through the lips, all the hairs uniting in its formation.

The quantity of hair imported for the use of our manufacturers in 1864 was—

	Cwt.	Value.
Ox and elk	63,771	£311,109
Horse	17,743	90,511

Bristles are the stiff, glossy hairs growing on the backs of wild and domesticated swine. They are imported into this country from Germany, Russia, Denmark, and Poland, and used in the manufacture of brushes for the hair, clothing, teeth, and nails. Russia is the great mart for bristles, those of the Ukraine being most esteemed; France also sends us considerable quantities. Bristles are of various colours—black, grey, yellow; but the kind called the lily, on account of its silvery whiteness, is the most valued, and is used chiefly for shaving brushes, tooth brushes, and the softer descriptions of hair brushes. In 1864 our imports from Russia were 1,958,112 lb., valued at £252,923; from Hamburg 207,274 lb., valued at £26,772; and from Prussia, Belgium, France, and other parts of Europe, 184,749 lb., valued at £23,346, making a sum total of 2,346,135 lb., valued in 1867 at £303,041. In 1867 the total import was 2,378,526 lb.

The Porcupine (*Hystrix cristata*, L.).—This animal is found throughout Southern Europe, and allied generic forms exist in North America. The porcupine quills sold in England are chiefly obtained from the European species, which is not common; therefore the quills are expensive. Work-piercers or eyeletteers for ladies, penholders, toothpicks, fish-floats, and fancy workboxes, are made from these quills.

VIII.—HORNS AND ALLIED SUBSTANCES.

I.—HORNS.

In zoology, all hard and more or less elongated processes projecting from the head are called horns. These natural weapons are either solid bone only, when they are called antlers, as in the stag; or they are composed of bone and horn, as in the sheep, goat, and ox. Horns of the latter kind consist of a hollow bony basis or core, on the surface of which is secreted a number of thin layers of true horny material. In the case of the giraffe, the horns consist of bone covered with hair, and are not deciduous. The horn of the rhinoceros is a mere appendage of the skin, and consists of horny fibres or hairs matted together. The antlers of the stag are shed annually, their fall being coincident with the shedding of the hair. True horns, or those which consist either partly or entirely of horny material, are never shed.

Chemically considered, horn may be regarded as intermediate in composition between albumen and gelatine, with a very small per-centage of earthy matter. There is a graduated connection subsisting between the substance of horns, nails, claws, hoofs, feathers, scales, hair, and even skin. The animals that supply horn for our manufactures are principally oxen, bulls and cows, goats and sheep, their horns being preferred on account of superior whiteness and transparency.

The first process in horn manufacture consists in effecting a separation of the true horn from its bony basis. This is accomplished by macerating the horns in water, which causes putrefaction of the membrane lying between the core and the horny sheath, and renders the former easily separable from the latter. The horn then goes through the processes of scalding and roasting, which soften it, and render the laminæ capable of separation from each other. It is next slit with a strong pointed knife; and by the application of a pair of pincers, one to each end of the slit, the cylinder or cone of horn is opened until it is nearly flat. These flats are then placed on their edges, vertically, in a strong iron trough, having between them plates of iron, half an inch thick and eight inches square, which have been previously heated and greased. These plates are now powerfully compressed by means of wedges driven in at the ends, the degree of pressure depending on the use to be made of the horn. For the leaves of lanterns, it must be sufficiently strong to break the grain or cause the laminæ of the horn to separate a little, so as to allow of the introduction of a round pointed knife between them, to complete the separation; for combs, a very slight degree of compression is enough, otherwise the breaking of the grain would cause the teeth of the comb to split at their points. The sheets of horn are next removed from the press and placed, one at a time, on a board covered with bull's hide, secured with a wedge, and scraped with a draw-knife, having a wire edge turned by means of a steel rubber. When reduced to the proper thickness, the horn plates are polished with a woollen rag dipped in charcoal powder, a little water being added from time to time; they are then rubbed with rottenstone, and finished with horn shavings.

When combs are ordered which are too large to be made from a single plate of horn, two or more plates may be united by the skilful application of pressure and of heat, sufficient to melt the horn; and when well managed, the line of union cannot be detected. The Chinese are very skilful in this kind of work, as is evident from their large globular lanterns, some of which are four feet in diameter, and which are made of small united plates of coloured and painted horn. The painted toys known as Chinese sensitive leaves, which the heat of the hand or of a fire will cause to curl up as if alive, are made from the best of the thin films of horn scraped off the plate by the draw-knife.

Horn is easily dyed, as can be seen in the above-named lanterns of the Chinese. In this country it is usually coloured of a rich reddish-brown, and spotted to imitate tortoise-shell. This is effected by boiling together, for half an hour, a mixture of red-lead, pearlash, quicklime, and a little pounded dragon's-blood, and applying the mixture hot to the parts of the horn which it is intended to colour. If a deeper colour be required, a second application of the above mixture must be made; and for a blacker brown, the dragon's-blood is omitted.

AGRICULTURAL DRAINAGE AND IRRIGATION.—IV.

By Professor Wrightson, Royal Agricultural College, Cirencester.

VARIOUS METHODS OF DRAINAGE.

The various methods of drainage employed owe their existence to facts duly considered in the last lesson—namely, the different characters of soil with which the drainer has to cope, and the three modes in which land suffers from wetness. First let us glance at the method practised by Mr. Elkington in the latter portion of last century. That Mr. Elkington's method of procedure in draining land attracted general attention is clearly shown by the fact that, as soon as the Board of Agriculture was established, and in consequence of a motion made by its President on the 10th of June, 1795, the House of Commons voted an address, "That His Majesty would be graciously pleased to give directions for issuing to Mr. John Elkington, as an inducement to discover his mode of draining, such sum as His Majesty in his wisdom shall think proper, not exceeding the sum of £1,000 sterling."

As Mr. Elkington's health was at that time failing, the Board resolved to send Mr. John Johnstone on a visit of inspection with the great drainage authority, to report on all that he saw in his tour. Such was the origin of the volume which contains the only account of the work of a remarkable man and a leader in agricultural improvement. A new edition appeared in 1841, from which we gather the following information:—In the year 1763, Mr. Elkington was left by his father a farm called Princethorp, in the parish of Stretton-upon-Dunsmore, in Warwickshire. The soil of this farm being poor and wet, as well as unsound for sheep, he determined to drain it. He commenced with a wet clay field, which was almost a swamp, and in some places a shaking bog, in consequence of springs issuing from an adjacent bank of gravel and sand. In order to drain this field, a trench was cut a little below the upper margin of the bog, about four or five feet deep. This trench ran parallel with the bank of sand just named, and after proceeding with it for some distance in this direction, he found that the main source of the water was evidently not yet reached. While considering what plan to pursue, a labourer happened to come into the field with an iron crowbar, an implement commonly used in

making holes for hurdle-stakes in folding sheep on the land. Mr. Elkington, suspecting that his drain was not deep enough, and wishing to know what kind of stratum lay under it, took the bar and forced it down about four feet below the bottom of the trench. On withdrawing it, to his astonishment a great quantity of water burst up through the hole he had thus made, and ran down the trench. This singular experience was the first of a series of similar trials and successes, which, since they can only be associated with a particular arrangement of the superficial strata, need a few words of explanation. The diagram shown in Fig. 2 represents the section of the field in which this remarkable discovery was made. It will be observed that the upper portion of the sloping ground forming the field is of gravelly and sandy character, and that at some distance beneath the surface is a clay bed, which would offer an obstruction to the downward passage of water. Upon it, then, water will accumulate. It will also be pent in by the clay and peat bed shown in the drawing. The water then rises until it reaches a point over which it can overflow, and this it does in the form of springs along the line which indicates the higher water level. The consequence is that the land on the surface immediately below this outlet of springs is rendered wet and boggy, until in its downward passage the water once more meets a porous rock, through which it disappears, still following the line of clay and leaving the surface dry. This, then, was the state of the field when Mr. Elkington undertook to drain it. The trench shown in the figure was cut parallel with the line of outbursts of springs, but it was not deep enough to reach the real source of wetness. It was at this point that the auger was found useful.

Piercing below the bottom of the trench, the water-bearing stratum was tapped, and the withdrawal of the crowbar was followed by a rush of water, at that depth under considerable pressure. It is clear that the consequence of this liberation would be the lowering of the water-table from the higher level down to the level of the bottom of the drain. The springs would immediately be dried, and the land below rendered sound. This, then, was the principle of Elkington's mode of draining —a method requiring an alternation of porous with tenacious strata, and evidently unfitted for soils wet from direct rainfall. Great sagacity, gained only by experience, and assisted by considerable geological knowledge, is requisite before it can be successfully applied, even in situations where it will be most likely to succeed. These qualities were possessed by Mr. Elkington in a marked degree, insomuch that his power of tracking a spring to its source appeared almost instinctive. It is not our intention to enter minutely into this system of drainage. The case of the field in which the discovery above described was made is a key to the method used by Mr. Elkington in countless other cases. Thus, if we examine carefully the nineteen plates illustrative of these drainage works found in Mr. Johnstone's work we shall find an almost tedious repetition, and occasionally an almost incredible arrangement of strata. All, however, point to the same principle—namely, that where land is wet from the accumulation of water upon a clay, and its rising until it finally bursts out in springs wetting the surface, under such circumstances the land can only be dried by an arrangement of trenches which will attack the source rather than the supply of water. One more case is, however, of interest, and that is where water is afforded an artificial passage through a clay bed into a porous stratum beneath, and thus got rid of. This is a method of drainage which may occasionally be carried out where there is a difficulty in finding a surface outlet. In such a case, if the underlying strata are suitable, a hole may be bored through the retentive material which bears up the water down into the underlying porous rock, which will then be used as an outfall for surface water. Lastly, the auger or boring apparatus must not be looked upon as involving no principle, but merely as saving excavation. In all cases deepening the trench would answer equally well as a means of reaching the water-bearing stratum, but this is done by a boring implement with less expenditure of labour.

The late Mr. Smith, of Deanstone, is credited with having originated the system of drainage usually employed at the present time. His practice was given to the world in 1823, and since then it has been modified by the materials used in constructing the underground channel rather than in any point of arrangement. This system is essentially uniform. Assuming that the source of wetness is co-extensive with the land, the Deanstone method consists in laying down a regular system of underground drains at equal distances apart and of equal depth. As these channels very frequently follow the line of ridge and furrow used in ordinary cultivation, the system has obtained the name of "furrow draining," and because it proposes to thoroughly and uniformly dry the soil, it has been spoken of as "thorough draining." These furrow drains enter a common channel of larger size, which is called the "main drain," and this carries the accumulated water of all the furrow drains to a suitable "outfall." The arrangement of furrow drains, connected at their lower extremities with main drains, has suggested the name of the "gridiron system," and the fact that furrow drains occasionally are made to enter on both sides of a main has conferred the title of "herring-bone" upon this system of drainage. We notice these various designations because they will enable the reader to at once realise, and without any difficulty, the main features of the method of drainage which, from the name of its inventor, is known as the Deanstone system.

At a future time we hope to minutely describe the drainage of a field, and to consider every possible difficulty that may be met with. The following brief sketch must, however, for the present suffice.

A suitable outfall is the first care of the drainer, and this will be the lowest point of the system of underground pipes. Next we have the main drain, extending from the outfall and following the lowest line of ground, either along the foot of a hill or the bottom of a valley. Then the position of the furrow drains is fixed, following, as a rule, the line of greatest slope, and entering upon one or both sides of the main drain as may be determined by the contour of the ground which it is desired to relieve of surplus water.

Such is the general plan, which hardly requires further illustration. The outfall should be made at a sound point in the bank of some neighbouring open watercourse, where there is no danger of the bank being washed away by the restless stream. Neither should outlets be multiplied, since each may be looked upon as a point of weakness, liable to invasion from animals and injury from accidents. Further, they must be made strong and secure, furnished with an iron mouth extending a few feet in the direction of the drain, fenced with an iron grating, and faced up with mason-work. One outlet ought to suffice for ten acres of land. With regard to main drains, they must be large enough to hold the water sent down to them from the furrow drains. They should also be a few inches deeper than the smaller drains, and this extra depth must be used to secure a rapid fall of the furrow-water into the main drain. Furrow drains must not be made to enter the two sides of a main exactly opposite to each other, but alternately, as shown in Fig. 3.

Again, cases occur in which the bottom of a valley is flat. Here the fall of the furrow drains will end before they reach the main drain, and the consequence will be a check to the flow of water. A double main drain* must in such cases be made. Each recurring furrow drains only on one side. Such an arrangement will secure the drying of the intervening space between the mains, as these will act as ordinary drains upon the soil in their immediate vicinity. The chief points to decide with reference to furrow drains are their depth and distance apart, which will be governed in all cases by the character of the soil that is to be drained. As, however, some of the points already brought under notice will receive further elucidation, we shall reserve them for more complete discussion when we consider the details of drainage work.

MATERIALS.

Any material will suffice for the underground channel which is cheap, portable, durable, and, at the same time, fitted for allowing water a free passage. A passage for water is, indeed, all that is requisite, and hence the fact that draining has been and is often practised without the help of any extraneous material, the sides of the channel being formed from the earth itself, just as the rock perforated by a tunnel, or the sand pierced by

* An illustration of this kind of drain will be given in a future lesson.

a rabbit, form of themselves the walls of the aperture. Among the most evanescent materials which have been used are thorns. Although these, when protected from changes of temperature and from the air, remain in activity longer than we might expect, yet after incurring the expense of digging the trenches it is exceedingly unwise to use them, as they cannot be looked upon as forming permanent channels for water. Captain Walter Blythe recommends "good green faggots, willow, alder, elme, or thorne," which, together with stones, were about the only materials of a lasting character to be had at the time. Mr. Smith of Deanstone, so late as 1823, named stones, broken to such a size as to pass through a three-inch ring, as suitable material for furrow drains, but preferred water-worn or rounded pebbles when they could be obtained easily. The receiving or main drains were to be formed of a culvert of stonework or of tiles. Where there is an abundant supply of stones in the immediate vicinity of the drainage works, it may even at the present day be economical to use them as drainage materials, and if well handled there is no reason why they should not make an efficient channel.

Stones may be built into a square or a three-sided A or V-formed culvert. They may be also broken and placed in the bottom of a trench. In this case a harp or screen is used for separating the large from the smaller stones, the larger being placed at the bottom, and the smaller forming the top of the channel. This arrangement prevents the infiltration of earth and final stopping of the drain, which would be unavoidable if a reverse order of disposition was used. The security of the drain is also further ensured by a layer of straw on the top of the smaller stones, which as it decays will form a protective coat between them and the loose soil above.

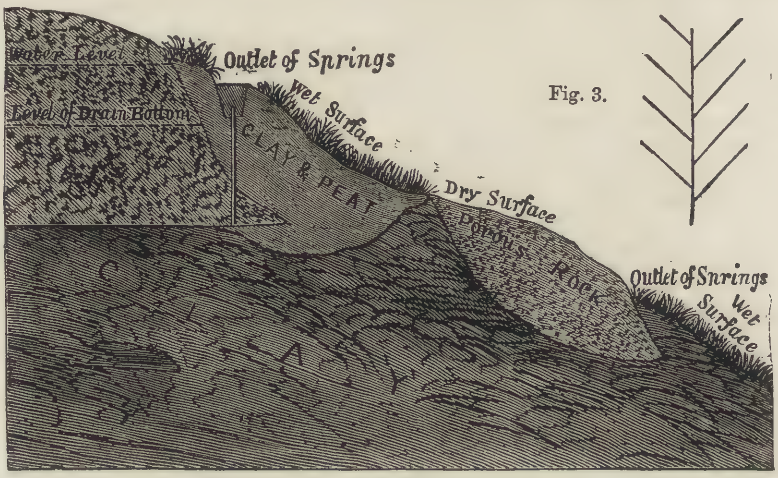


Fig. 2.

The draining tile is by far the best material for the purpose, and as it has passed through several modifications of form it will be well to glance at its history. The first efforts to manufacture draining tiles resulted in cumbrous and expensive fabrications, having few if any points to recommend them when contrasted with stone drains. They involved the same wide trench—one of the most fatal failings of stones as a drainage material. The modern pipe allows of the minimum amount of digging in forming the trench, and this is one of its leading advantages.

The horse-shoe—or, as it might with propriety be named, the U-formed—tile appears to have been used as early as 1760 at Crandesburg Hall, in Suffolk, by Mr. Charles Lawrence, the owner of the estate (Gisborne), and these, with slight alterations and improvements in form and material, were used until very recent times. This tile was open to two serious objections. Its horse-shoe form was a cause of weakness, as when the sides of the trench began to be pressed inwards by lateral pressure and the swelling of wet clay, the tile was apt to break longitudinally along the crown. Another source of failure was from the pressing upwards of the bottom of the drain, owing also to the weight of earth on either side. This upward pressure, combined with the wearing action of water in the drain and the gradual settling of the tile, soon caused an interruption of the channel, the tile becoming full of earth. An attempt was made to overcome this failing by forming a round or rather elliptical drain, placing two horse-shoe tiles one above the other, the lowermost one being upside down, and "soles" were also introduced for the purpose of preventing the sinking of the open tile. Still the breakage of the tile from pressure continued, and rendered the work liable to failure. The next improvement consisted in making the tile and sole in one piece, forming a D-shaped tile, and thus the way was prepared for the last important innovation, the round draining pipe. So far back as fifty to sixty years ago, pipes for land drainage were concurrently used by Sir T. Wichcote, of Asgarby, Lincolnshire; Mr. R. Harvey, of Epping; Mr. Boulton, of Great Tew; and Mr. John Read, at Horsemonden, Kent. Mr. Boulton's were one-inch pipes, and it is an interesting fact (which we derive from Mr. Gisborne's valuable essay) that these were made of porcelain by Wedgwood at Etruria, showing that in the same works where exquisite medallions and vases of a character adapted to elevate public taste were being executed, attention was also being given to the development of a less beautiful but equally important manufacture. The general adoption of pipe-tiles did not, however, take place for some years later. In Vol. IV. of the Royal Agricultural Society's Journal for 1843 two excellent papers appeared upon land-drainage, the first by Mr. Thomas Arkell, of Stratton St. Margaret's, Swindon, and the second by Mr. Robert Beart, but in neither of them is any other tile mentioned or figured, but the ordinary horse-shoe tile with soles.

In the same volume is to be found a report by Mr. Josiah Parkes, consulting engineer to the Society, upon drain-tiles and drainage. "The society had offered a premium of ten sovereigns for the drain-tile which should fulfil certain specified conditions, but it was found quite impossible in the show-yard to authenticate the facts required; consequently this prize was not adjudged." A silver medal was awarded by the judges to Mr. John Read, 35, Regent Circus, Piccadilly, for specimens of cylindrical or pipe tiles invented by him. These tiles were from 1 to 2 in. internal diameter, twelve inches in length, and were offered at £1 to £1 14s. and £1 18s. per thousand. "It does not appear," writes Mr. Parkes, "that pipes have been anywhere used for land drains at a period more remote than thirty-five years since, about which time Mr. John Read made and employed them, when servant to the late Rev. Dr. Marriott, of Horsemonden, in Kent. These were about three inches in diameter, and were made by bending a sheet of clay over a wooden cylindrical mandril. This simple form of tile was well adapted for a more rapid mode of manufacture."

Fig. 3.

It would occupy too much space to enter at any length into particulars regarding the different machines which have been brought out for perfecting the manufacture of tiles. Mr. Pusey relates, in Vol. III. of the Royal Agricultural Society's Journal (1842), how the cost of tiles had been a great check to their employment, and how, about two years previously, while 40s., 50s., and 60s. per thousand were paid for tiles in the south of England, Mr. Beart, of Godmanchester, had five years before invented a simple machine by which he had reduced the price of tiles from 40s. to 22s. throughout Huntingdonshire. The Marquis of Tweeddale followed with a most ingenious machine, and at the Bristol meeting Mr. Irving exhibited an apparatus for the same purpose. Formerly tiles, whether cylindrical or horse-shoe shaped, were perforated with occasional holes to allow water to enter easily. This is, however, quite unnecessary, as water will have no difficulty in penetrating through the porous material of which they are formed, and when we remember the joints which occur between each tile, it is evident that there is enough space for its entrance.

COLOUR.—III.

By Professor CHURCH, Royal Agricultural College, Cirencester.

PRODUCTION OF COLOUR BY TRANSMISSION, ETC.—MUTUAL RELATION OF COLOURS.

THE absorption and reflection of light are very closely related, yet there are many coloured bodies which instead of absorbing some rays and reflecting others, transmit those rays which they do not reflect. Even a third condition exists, in which a substance reflects some rays of the incident light, transmits others, and absorbs the remainder. We may now briefly consider the production of colour by these three methods.

Let us suppose a substance which appears red by reflected light and red also by transmitted light. Of the white light which has fallen upon it and which it has decomposed, it has absorbed or quenched all the colours save the red; while of the red it has transmitted part and reflected part. But the instances in which a substance appears of a very distinct colour owing to reflection are rare. A few metals may be cited as examples along with such substances as murexide, magnesium platinocyanide, potassium permanganate, and indigo. The yellow colour of gold is due to selective reflection. A plate of this metal reflects much of the incident light unchanged, but it quenches in another portion much of the violet and other very refrangible rays, and so leaves the residual red, orange, and yellow rays to produce their colouring effect. It might seem likely that gold would transmit when in sufficiently thin leaves all those coloured rays which it does not reflect. This is true to a great extent; still the grass-green light which a leaf of gold transmits is not perfectly complementary to the orange-yellow which it reflects, some of the constituent rays of the original white light having been absorbed. Solid indigo affords us a similar example of selective absorption and reflection. If a lump of pure indigo be pressed with an agate burnisher, a copper-coloured streak makes its appearance. As long as the substance of the indigo is not coherent—that is, as long as it is in minute powdery particles—so long it shows no symptom of a copper-coloured reflection, but is blue. Now the blueness of powdered indigo thus seen by reflection is not really produced by or in reflection, but rather during transmission of light from particle to particle of the powder. A chromatic selection is thus made, and the light finally reflected to the eye has been deprived of several of its coloured elements. Increase the coherence of the blue indigo powder either by pressure, or by the chemical process of sublimation, by which crystals may be formed, and then, though the transmitted light will remain blue as before, the reflected light will be chiefly copper-coloured, having been deprived by reflection itself of its blue and some other constituent rays. The foregoing facts often suffice to explain the great difference in colour between a solid substance and its powder.

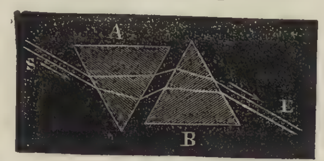


Fig. 4.

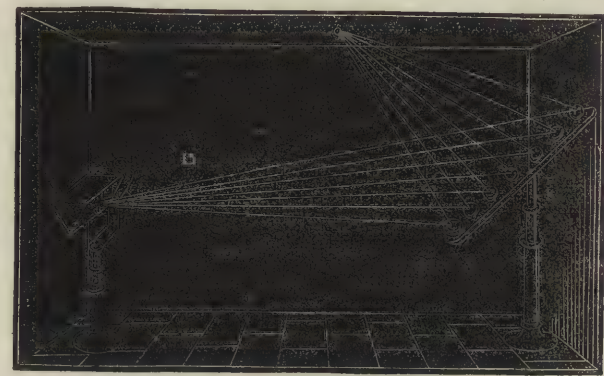


Fig. 5.

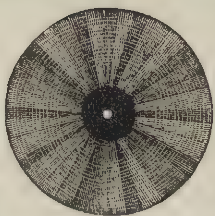


Fig. 6.

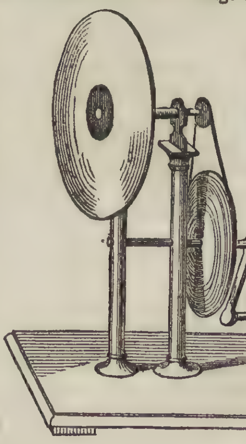


Fig. 7.

Substances which are commonly regarded as transparent are never perfectly so. Neither water, nor flint glass, nor rock crystal, permit all light-rays to travel freely through them. Some substances, such as solutions of the rare metal didymium, and certain specimens of the mineral known as zircon, absorb or cut off several of the rays of solar light, and yet do not appear perceptibly coloured. The residual transmitted rays in such cases suffice to produce white light. Very thin layers of coloured substances, such as films of tinted liquids, may seem colourless, and yet, when we increase their thickness, colour becomes perceptible. Not only does colour become perceptible, but the colour varies with the thickness. A crystal of blue vitriol shows on its thinnest edges a greenish tint, which alters to a pure blue in the mass. Such a change as this is easily explained. A thin plate of blue vitriol transmits all the blue, a good deal of the green, and a very little of the remaining rays of the spectrum. If we double the thickness of the plate the effect is increased, not in arithmetical but in geometrical proportion. Ultimately, by the extinction of all the rays save the blue, the transmitted light becomes sensibly an homogeneous blue. A very easy mode of observing the striking differences in colour between thin and thick layers was devised by Professor Stokes. A fine slit (one-fiftieth of an inch across) between two blackened metallic edges is adjusted vertically in a blackened piece of board; behind the slit is a source of light, such as a bright flame or the sky. Hold the prism, having an angle of 60°, against the eye; by adjusting the position of the prism a pure spectrum will be obtained, showing, if solar light be used, the principal fixed lines. Now, to observe the absorption of any liquid, fix a test tube or flat cell containing the liquid to be examined behind the slit. Begin the experiment by using a very pale solution, and then gradually increase the strength, noting the gradual appearance of dark lines or spaces in the spectrum and the blotting out of colour after colour. If a wedge-shaped trough be used to hold the coloured liquid behind the slit, it may be gradually moved so as to interpose thicker and thicker layers of the coloured liquids, and thus to produce the same results as those obtained by gradually increasing the strength of the solution. This method is of service when we wish to know the result of diluting any coloured liquid which has to be employed for artistic purposes. Thus, it will be found that some reds, when diluted, instead of becoming pink, pass through orange to yellow; while some blues, instead of becoming paler blues when weakened, become either green on the one hand or violet on the other.

We turn now to the re-composition of white light from its constituent elements. There are several ways of accomplishing this result. If we receive the spectrum of coloured rays produced by one prism on another precisely similar prism, but inverted (Fig. 4), the emergent beam, E, will be white. The concentration of a spectrum by a bi-convex lens or a concave mirror gives a white and not a variegated image. Or the seven so-called principal colours of a spectrum may be received upon seven little mirrors (as shown in Fig. 5), and then these mirrors may be so adjusted that their separate images are superposed. In this case also a single white image is obtained.

A less perfect mode of re-uniting colours so as to form white may be accomplished in the manner suggested by Newton. A disc (Fig. 6) is painted in radiating segments with the nearest approach afforded by pigments to the seven colours of the spectrum, the centre and edges being made black. The relative areas of the several colours must be adjusted so as to correspond as far as possible with the normal spectrum, introducing, however, such

differences as the imperfections of the pigments used may demand. As red, green, and blue are the most prominent colours of the spectrum, they should be used in larger proportion than the orange, yellow, indigo, and violet. Indeed, a very respectable kind of whitish grey may be obtained by the use of fewer colours than seven; but of this point we shall have occasion to speak more definitely further on. The best pigments, however, even when used in proper proportions, do not produce a perfect white when the disc painted with them is rapidly revolved (see Fig. 7), so that the retina receives in quick succession the impression of the whole series. All coloured bodies absorb much light and do not reflect really homogeneous rays, and a grey is the reult. If several series of similarly coloured segments be painted on the disc the grey more nearly approaches white. In the latter case the eye receives simultaneously the impressions of the several colours, and so the effect does not wholly depend upon the long persistence on the retina of these impressions.

We may now turn our attention to the mutual relations of the several colours.

Reverting for a moment to the pure solar spectrum obtained by means of a prism and a slit, and with the exclusion of all extraneous light, we may first of all notice that it consists mainly of three colours—red, green, and blue. These coloured bands occupy by far the largest area of its most brilliant portion. The orange, yellow, and sea-green, though more brilliant, are very limited in extent, while the indigo and violet region of the spectrum is much less conspicuous. Now for many practical purposes the theory of the existence of only three primary or elementary colours will be found very useful. The selection of these primary colours has, however, been far from unanimous, one set of observers choosing scarlet, green, and blue, another yellow, red, and blue. Nearly all writers on the artistic aspects of colours, such authors as Chevreul, Field, Redgrave and Hay, have accepted the latter selection; but though it undoubtedly affords an easier means of studying the nature of the mixed colours which pigments and paints afford, it is but partially supported by experiments with the pure colours of the spectrum, and in some points is positively contradicted by them. The rival theory, in which the three primaries assumed are scarlet, green, and blue, has been profoundly studied by Maxwell, and has been made the basis of a small treatise on the science of colour by Mr. W. Benson, a London architect, who has done much to further the acceptance of this comparatively modern theory. We shall proceed to give an outline of both views as to the relations of the colours of the spectrum; thus our readers will be able to form their own judgments on the two theories. For our own part we regard Maxwell's experiments as conclusively proving most of the positions he has laid down when pure coloured lights are the subject of comparison and experiment. Yet in actual work with pigments themselves, the older theory affords a more immediate, though often a less exact, answer to any question which may arise.

In order to study the primary or simple, and the secondary or mixed colours, several methods may be pursued. We here name three of the most important of these methods.

Tint two pieces of paper with the two colours to be examined, place the coloured pieces an inch or two apart on a piece of black velvet, and set up, equidistant between them, a slip of thin, colourless plate glass; then adjust the eye so that one coloured patch may be seen by reflection from the near surface of the glass, coincident with the other patch as seen directly through the glass. By inclining the glass the reflected image of one colour may be altered in intensity, and so the relative proportions of the two colours may be varied at pleasure.

Another plan, devised, like the last, by Helmholtz, consists in obtaining two intersecting spectra. Two clean-edged narrow slits, forming together a right angle, thus V, are made in a metallic plate. When this compound slit, brightly illuminated from behind, is viewed by means of a prism about twelve feet off, two overlapping spectra will be seen, the prism being held vertically. As each coloured band of one spectrum crosses all the coloured bands of the other, the result of combining two of the spectrum colours together may be studied. For this purpose it is desirable to employ solar light, the fixed lines of which afford a means of identification of the several colours, and may be readily seen in the above-named spectra by means of a telescope. The telescope is furnished with cross wires, and a diaphragm for limiting the field of view, placed a short distance from the eye-piece of the telescope and close to the eye. A third slit may be used, if it be desired to unite three coloured rays. A modification of this method of producing overlapping spectra consists in cutting out from a piece of white cardboard three pieces of the shape indicated in Fig. 8 by the black spaces. The perforated cardboard, which should be of large size, is placed in a bright light with a piece of black velvet below it. It is then to be viewed six or seven yards off with a prism having its refracting angle turned away from the eye, and placed at right angles with the edge A B of the cardboard figure. No description can give an idea of the beauty of the overlapping spectra thus produced. The results obtained by Helmholtz and Maxwell, by means of experiments conducted by the method of overlapping spectra, will be described below.

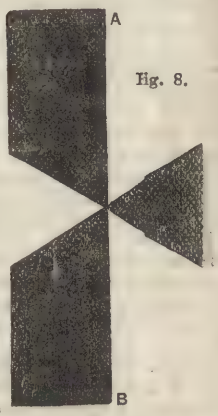


Fig. 8.

A third method of combining colours is by means of a revolving disc such as that represented in Fig. 7. The disc may be painted with the colours it is desired to combine, and then rotated. Of course the proportions of the colours used may be varied not only by painted segments having different areas, but by the superposition of a second or third disc upon the original one, the additional discs having segments of different areas cut out, and being themselves either white, black, or coloured. The various kinds of colour-tops and kaleidoscopic tops may be used for these experiments. We may now give the chief results obtained by Helmholtz and by Maxwell, by means of the first and second methods above described, premising that the statements refer to the coloured rays of the pure spectrum, and not to those of pigments

Helmholtz concludes that there are five primary colours. These are red, yellow, green, blue, and violet. With these, two or three together, and in various proportions, he obtained nearly perfect representations of the mixed colours. Many combinations of three of them yielded white light. A great range of mixed colours may be obtained by variously combining red, green, and violet. Helmholtz considers these three as affording better results than red, green, and blue, which Maxwell regards as the only essential primary colours, and as infinitely preferable to the older selection of red, yellow, and blue. With regard to the mixture of colours, it appears that the following are among the most important of Helmholtz's results:—

Red + bluish-green = yellow.
Red + bluish-green + indigo }
Red + greenish-blue }
Yellow + indigo } white.
Orange + blue }

The two most remarkable of these results are the facts that red and bluish-green make yellow, and that yellow must therefore be regarded as a compound colour. When this yellow is united with the deep blue called indigo, it produces white. Here we have two conclusions quite opposed to the result obtained by mixing pigments. When vermilion and emerald green are mixed, a grey with merely a suspicion of yellow is the product. When chrome yellow and indigo are mixed, a distinct green is the product. We have before alluded to the causes of such discrepancies, but may now explain them so far as relates to the examples just cited, since these are typical cases of the kind, and illustrate the two chief points in which the new theory of primary colours differs from the old. Vermilion reflects chiefly red and yellow light to the eye; emerald green chiefly green, but also a little blue and yellow. Mix these coloured powders together, and most of the red, green, and blue they reflect, as long as separately viewed, is either absorbed or re-combined into whiteness, little else remaining but the small quantity of residual yellow rays common to both. Similarly with chrome yellow and indigo; the chief colour they reflect in common is green, and so most of the other rays which they reflect when separate are either quenched when they are mingled, or overpowered by the combined and enhanced effect of the green common to both pigments.

We shall proceed in our next lesson with the account of the new theory of colour by giving some of Maxwell's results.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

V.—JAMES BRINDLEY, ENGINEER.

BY JAMES GRANT.

In a very small cottage that has long since fallen into ruins, and the site of which is only marked by an enclosure called Brindley's Croft, three miles from Buxton, James Brindley, one of England's greatest engineers, was born in 1716. His father was a humble collier, fonder of sport than work, and neglectful of his children; but Mrs. Brindley strove to supply his place, by teaching them all the little she knew. James Brindley, in his seventeenth year, was bound apprentice to a wheel and mill wright at Sutton, near Macclesfield, and there he worked hard, but learned so slowly that his master on more than one occasion "threatened to cancel the indentures and send him back to farm labourer's work;" but in the second year "the bungling apprentice," as he was named, repaired without help the machinery of a silk mill so skilfully and so well that his master was delighted, and his fellow-workmen, ever full of jealousy of a new hand, were filled with mortification.

At the age of twenty-six, he began business on his own account at Leek, a small market town having only a few grist mills in its vicinity. Brindley had no capital save his skill and reputation as a thoroughly reliable workman, and from his tendency to *improve* everything, obtained the sobriquet of "the schemer." He soon had plenty of work among silk, paper, flour, and other mills; but his education was defective; he wrote and spelt badly. He obtained employment from the Brothers Wedgwood, whose flint mills in Burslem he erected with such success, that fame and business came together, and his reputation as an engineer began to spread. Thus he was employed by Mr. Heathcote, of Clifton, to drain the mines on his estate, an object effected by Brindley, who tunnelled through the solid rock for 600 yards to gain the fall of the river Irwell, leading the water to the breast of an enormous water-wheel fixed in a chamber thirty feet below the surface of the ground, from the lower end of which, after exercising its power, it flowed away into the lower bed of the Irwell. This cleared the mines of water, enabling the men to get coal in seams from which they had long been excluded. Machinery for a silk-mill at Congleton was his next work, and after much quarrelling with the superintendent, who taunted him as a "common wheel-wright," he got the construction of the entire mill placed in his own hands; and the result was that, when finished, it was found to be one of the most complete and economical arrangements of manufacturing machinery that had ever been erected in the neighbourhood.

The improvement of the steam-engine next occupied his attention, as he conceived it possible to work it with less fuel than was at that time used; so in 1756, when erecting one for Mr. Broade, in Staffordshire, he adopted the expedient (afterwards tried by Watt) of wooden cylinders instead of iron; he substituted wood for iron in the chains which worked at the end of the beam. Like Watt, he had to relinquish the wooden cylinders; but surrounding the metal ones with a timber case, filling the intermediate space with wood ashes, and by this means using no more injection of cold water than was necessary for condensation, he reduced the *waste* of steam to one-half. This work cost him great anxiety; but the year 1758 found him constructing a new and improved steam-engine, the specification of which he duly lodged at the Patent Office on the 26th of December. In its formation a great deal of wood was to be used, for he seems long to have retained his mill-wright predilection for that material; but he had completely discarded it by 1763, when he came to erect the engine for the Walker Colliery at Newcastle, which Stuart has pronounced to be "the most complete and noble piece of iron-work" that had up to that time been produced.

Brindley's growing fame now brought him in contact with the famous Duke of Bridgewater, who after his racing exploits, his love affair, and his disappointment, retired to Worsley and betook him to canal-making, and had revived an old Act of Parliament which empowered his father to make Worsley Brook navigable to the point at which it entered the Irwell. But the young duke had the Act framed in a new form, which enabled him to cut a navigable canal from Worsley Mill to Salford, and thence to a point on the Mersey called Hollin Ferry; and the people of Manchester hailed the event as a great public boon. This was the first project in England—unless we except some of those of old Andrew Yarranton—for cutting a navigable trench through the dry land, and Brindley was consulted by the duke, who was much impressed "by the native vigour and originality of the unlettered genius," with whom he was now brought in contact, and to whom he entrusted the entire conduct of the proposed work.

Brindley's ideas on the subject were thoroughly original. He suggested that, instead of carrying the canal down to the Irwell by a series of locks, such as never before had been attempted in England, it should be carried right over the river, and constructed on one entire level throughout, filling up the low ground on one side of the Irwell by a mighty embankment, and uniting with the land on the other by a lofty aqueduct of stone. In the course of making arrangements for this, at that time, great undertaking, Brindley had to make many journeys to London, which he always performed on horseback, proceeding in summer by Coventry, and in winter by the Great North Road; and the new Act, permitting the duke to carry out his canal according to Brindley's new plan, passed the House in the first session of 1760; but instead of going to Hollin Ferry, it was to be carried over the Irwell near Barton, five miles west of Manchester, by a series of arches, and to vary its course accordingly, with a short branch to Longford Bridge, near Stretford. To attempt a description of this canal would be beyond our space. The Barton Aqueduct is 200 yards in length and 12 yards wide, sustained by a bridge of three arches, the centre of which has a span of 63 feet, carrying the canal 39 feet above the river.

Brindley's labours were not alone confined to the construction of the canal, for his attention was equally directed to the whole arrangements, and the machinery by which they were carried out, and in improving the duke's mines. In his time the subterraneous canal which enters the bottom of a hill at Worsley was only one mile in length; now it extends for nearly forty miles in every direction underground. He invented the cranes for more readily loading the boats with the produce of the mines, and laid down within the latter a network of railways, all leading to the wells which he had pierced at different points in the tunnels, through which the coals were shot into the boats waiting to receive them. After-years, when the use of the steam-engine became so universal, have proved what a vast boon this canal has been to Manchester and all its neighbourhood, by affording that cheap and abundant supply of fuel, which is of such vital importance now to the manufacturer.

Brindley was next employed by the duke in surveying the land between Stretford and the Mersey, for the purpose of cutting a canal in that direction, to aid the growing trade between Liverpool and Manchester, an important project on public grounds, and the duke at once took means to have an Act passed for his new scheme. Brindley was overwhelmed with business; but his note-book (as Mr. Smiles records) shows that he treated himself to *one* holiday at this time, and the entry may be taken as a specimen of his spelling: "the crounation of Georg and Sharlot," the new sovereigns of Britain. After much parliamentary opposition, Brindley had the pleasure of constructing the duke's new canal to Runcorn. The course of this important work, which unites the trade of Manchester and Liverpool, is twenty-four miles in length, lying entirely in new red sandstone; its principal earthworks consist of clays, marls, bog-earths, and occasionally the sandstones of the formation. Salemoor Bog was a serious obstruction; but to Brindley, difficulty was only a something to overcome, and he resorted to timber-casings and erect deal bulks, laid in rows and screwed together, to give consistency to the banks of the canal there. To provide against the chances of danger by the banks bursting at any point, he had stops or floodgates laid in various parts of the bed, so that in the event of a breach occurring, and a rush of water taking place, the current would have the effect of raising the valvular floodgates and so shutting off the stream, and preventing the escape of more water than was contained in that division of the canal; and in resorting to these ingenious expedients, it should be borne in mind that the unlettered Brindley had no previous experience to fall back upon, and no literary knowledge of the works of foreign engineers. All was the result of his own original thought.

Marvellous was Brindley's close application to the minutest details of business, for the purpose of economising work and money. "He seems to have settled with the farmers for their tenant right, sold and accounted for the wood cut down and

the gravel dug out along the line of the canal, paid the workmen employed, laid out the work, measured off the quantities done from time to time, planned and erected the bridges, designed the canal boats for conveying earth to form the embankments, uniting in himself the varied functions of land-surveyor, carpenter, mason, brick-maker, boat-builder, paymaster, and engineer. We even find him descending to count bricks and sell grass. Nothing was too small for him to attend to, or too bold for him to attempt, when necessity arose."

One of the most singular features in the history of this canal enterprise is that, although it yielded an income which eventually reached £80,000 yearly, it was planned and executed by Brindley at the rate of 3s. 6d. per diem, and for a great part of the time his fee was but half-a-crown daily! He was not insensible to the inadequacy of his remuneration, and was consequently somewhat independent in his bearing towards the duke, who was now completely lost to the world of fashion, and absorbed in the progress of his mills, canals, and coal-mines, and at times actually superintended the work on his own coal-wharf at Manchester, where he was once seen to lift a heavy sackful on a labourer's back.

Before the duke's canal was finished, Brindley was actively engaged in a greater enterprise, the canal which was to connect the Mersey with the Trent, and both with the Severn. Smeaton was joined with him in making a combined report on the practicability of the undertaking, for canals were as yet too untried in England to be hastily entered upon. Brindley suggested that the new undertaking should be called "The Grand Trunk Canal," as he sagaciously foresaw that many others would branch out from it, in the course it had to traverse. The innkeeper, pack-horse, and wagon interests made violent opposition, and foretold the ruin of England—even the decay of her merchant service—if this system of canals were pursued. However, the bill passed, and on the 26th of July, 1766, the first sod was cut by Josiah Wedgwood, the famous potter, on the slope of Bramhills, in Brindley's presence; and many of the leading persons present put their hand to the work by turns, each cutting a sod or wheeling a barrow of earth in honour of the event—the most formidable undertaking that England had yet seen.

The most important works on this canal were the five tunnels, the Harecastle, 2,880 yards long; the Hermitage, 130 yards; the Barnton, 560 yards; the Salternford, 350 yards; and that at Preston-on-the-Hill, 1,241 yards. When Brindley proposed to cut a navigable tunnel under the great ridge at Harecastle, he was laughed at as a waster of capital, a rash projector, and the small wits of the district spoke of it as his "Air Castle;" but the bold engineer set to work undauntedly. He sunk shafts from the hill-top to the line of his intended canal, and drew the stuff out in the usual way by horse-gins; wind and water mills carried off the subterraneous springs, and fire-engines and atmospheric engines pumped great volumes of water out by night and day, and the work was carried on at both ends of the tunnel at the same time, till the vast excavation was cleared, arched in, and completed. In two years' time, he had twenty-two miles of the navigation cut and finished, but it was not finally open until the year 1777. It soon caused the potteries of Burslem and Stoke to flourish, and new branches of industry to spring up. Thus, about ten years after the opening of the Grand Trunk, Wedgwood stated before the House of Commons that 15,000 to 20,000 persons were employed in the earthenware manufacture alone, while the annual import of clay and flint into Staffordshire was about 60,000 tons; and he added truly that the trade was but in its infancy, for now the outward and inward tonnage of the Potteries is far above 300,000 tons yearly.

As Brindley had foreseen, many branch canals were projected in connection with his Grand Trunk. One of these was at Wolverhampton, connecting the Trent with the Severn, and now known as the Staffordshire and Worcestershire Canal, opening up the coal-fields in districts now teeming with population, full of iron-works, and in direct connection with Liverpool, Hull, and Bristol. Brindley laid out three more canals in 1768: the Coventry Canal to Oxford, connecting the Grand Trunk system by Lichfield with London, and consequently with the Thames; the Droitwich Canal, to connect that town with the Severn; and another from Oxford to the Coventry Canal at Longford, a distance of eighty-two miles. Another of Brindley's canals, authorised in 1769, was that between Chesterfield and the Trent at Stockwith, for the transport of coal, lime, and lead from the mineral resources of Derbyshire. The entire length of canals executed by Brindley amounts to 365 miles, 5 furlongs, 6 chains. He was now looked upon as unquestionably at the head of his profession, and as the great authority on all questions of inland navigation.

In addition to his canal works, he was consulted as to the best mode of draining the low lands in different parts of Lincolnshire, and the Great Level in the Isle of Ely. He also supplied the Corporation of Liverpool with plans for cleansing the docks and keeping them clear of mud.

When close on his fiftieth year, he married a young girl named Miss Anne Henshall, daughter of a land-surveyor; and from that time, 8th of December, 1765, he resided at Turnhurst, which was conveniently near the works of the Harecastle Tunnel. James Brindley was perhaps one of the most remarkable examples of untaught genius that England has produced. He could scarcely read, and barely write; he could not spell three words correctly. The literary test cannot be applied to him, yet his works or undertakings gave an impulse to social activity, and greatly improved and influenced the condition of his countrymen in the midland and other districts of England. While surveying for a branch canal between Leek and Froghall, he got drenched by rain, and omitted to change his clothes. Diabetes shortly developed itself, and after a protracted and painful illness, he died at Turnhurst on the 27th of September, 1772, in the fifty-sixth year of his age, and was interred in the burying-ground at New Chapel, a few furlongs distant from the house of his young widow, who married again, and died so lately as 1826.

They had two daughters, whose descendants are now living in Tasmania.

THE ELECTRIC TELEGRAPH.—III.

By J. M. Wigner, B.A.

SUBTERRANEAN LINES—SUBMARINE CABLES—FIRST CABLE FROM DOVER TO CALAIS—ATLANTIC CABLES—PERSIAN GULF CABLE—SIEMENS' CABLE.

Subterranean lines are but seldom employed except in special and peculiar circumstances, as, for example, in connecting important fortresses or military stations with one another. In case of an invasion all ordinary lines would at once be cut; but if an underground wire has been laid by a circuitous and well-chosen route, it is very difficult to discover it. In the present French war several of these lines, connecting different fortresses, have been discovered and cut, but not till after they had rendered good service to the besieged.

Submarine lines are of much greater importance than these, and have demanded in their manufacture all the skill and ingenuity that could be brought to bear. To us, in our snug island home, they are especially important, and by their means we are now linked in electrical circuits with all neighbouring countries as well as with several which are very remote from us.

The first attempt at a submarine cable consisted of a wire coated with gutta percha, which was laid between Dover and Calais in 1850; but this was so imperfect that it failed after the first day. A fresh attempt was, however, made the next year with much increased success. The cable laid on this occasion is represented in Fig. 9, which shows a section of the true size.

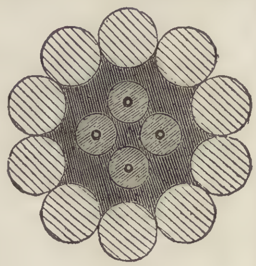


Fig. 9.

The conductor consisted of four copper wires (No. 10 Birmingham wire gauge), each of which was separately insulated by being covered with gutta-percha. These wires were laid side by side, a little hemp being placed between them to prevent their chafing; tarred hemp was then laid on so as to form a solid rope, and outside all, as a protection against accidental injury, there were galvanised iron wires (No. 1 Birmingham wire gauge) spirally wound. The cable, when complete, weighed about seven tons per mile, and possessed very great strength.

It was found to answer admirably, and has remained in working order ever since.

This experiment having succeeded so thoroughly, many other lines were speedily projected and laid, most of which answered well. There have, however, been several failures, and these very costly ones; but they have been the means of drawing attention to defects in the mode of manufacture, so that in the present day success is almost certain, even when the length of the cable is very great.

It will easily be seen that the risk and difficulty increase in a very rapid degree with the length. A few very minute imperfections, so trifling as only to be discovered by the greatest care and scientific skill, will suffice to render a long cable almost useless, and it is very difficult to get at them so as to repair them when once the cable is laid. The pressure of the water, too, at the bottom of the sea is very great, and thus any flaw soon becomes manifest, as the water is forced into it, and makes an escape for the electricity.

The whole of a cable is now constantly and carefully tested during all the processes of its manufacture, so that there is but little chance of a defect passing unobserved. The core after being made is submerged in water, and after remaining so some hours is carefully tested; should any portion prove defective, the exact position of the fault is ascertained, the defective piece is removed, and the core spliced again. The same process is repeated when the cable is complete; and during the process of laying currents are continually transmitted along it, so that faults, should there be any, may at once be detected and removed.

In 1853 a cable was laid between Dover and Ostend; this was very similar in construction to that already figured, but it contained six conducting wires instead of four. More recently this plan has been almost given up, and each cable now usually contains only one conductor, though this is often composed of several wires twisted together.

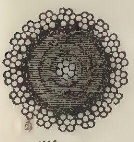


Fig. 10.

In 1856, so rapid had been the advance in the manufacture of telegraph cables that a project was started for making one to connect England and America, and in the summer of 1858 this was completed and laid. The deep-sea portion of this (Fig. 10) was much lighter than those already described, weighing only one ton per mile. The conductor here consisted of seven copper wires, No. 22½ gauge, twisted together. It was considered preferable to employ these instead of a single wire of larger diameter, as in case of any defect in one wire the current would easily be transmitted along the remaining six without being perceptibly interrupted. This strand was carefully covered by three coatings of gutta-percha, so as fully to insulate it; additional protection and strength were then imparted by a serving of jute saturated with tar and other preservative materials, and outside this, eighteen strands of iron wire were carefully wound on, each strand consisting of seven wires No. 22 gauge. Near the shore there is, of course, a much greater risk of accident than in the deep sea, where, when the cable is once laid, it soon becomes covered with sand or silt, and is practically safe from injury. In the shallow water the bottom is more affected by currents and storms, and hence a much stronger portion, known as the shore end, is spliced to the deep-sea part of the cable. In this first Atlantic cable the same core was used as for the deep-sea portion, but instead of the strands of fine iron wire, an extra serving of hemp was laid on, and outside this twelve stout iron wires were coiled, so that the diameter of this portion was nearly three times as great as that of the rest. The total length of the whole was a little over 2,000 miles. It was, however, far from successful; sufficient care was not taken in testing it; hence there were faults in it from the very first, and only a few messages were passed along it before communication entirely ceased. This experiment, being a very costly one, checked a little the manufacture of cables; but the causes of the want of success soon became apparent, and thus much valuable information was obtained even by the failure.

Two cables have since this been laid between England and America, both of which have answered well, though some serious difficulties were encountered in laying them.

Faults have occasionally been discovered, but these have been found to arise from injuries inflicted either by design or accident, and have been repaired. In laying one of these, the cable broke and the end was lost. The exact position was, however, noted, and suitable drags being obtained, the end was fished up from the bottom, spliced on to the new cable, and the whole completed. The fact of thus being able to find the end of a cable, lost at a very great depth, is perhaps one of the most wonderful recorded in connection with the laying of submarine cables.

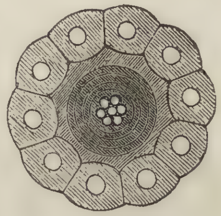


Fig. 11.

The former of these two cables is represented in Fig. 11. The core consists of seven No. 18 gauge wires, twisted into a spiral; this is covered with four coats of gutta-percha, alternating with thin layers of Chatterton's compound, which consists of 3 parts of gutta-percha, 1 of Stockholm tar, and 1 of resin. These bring the diameter of the core nearly up to half an inch. Outside this is a covering of hemp, well saturated with salt water, and an outer layer of ten wires of homogeneous iron. The peculiarity here is that each of these is separately surrounded by Manilla yarn, saturated with a preservative compound. For the shore end a portion of the completed deep-sea cable is used, but it is further strengthened by another layer of hemp, and some more wire strands. For submerging this cable the *Great Eastern* steamer was employed, fitted with large tanks, in which the cable was coiled and kept submerged till it was laid. All the core was tested in water at a considerable pressure before it was made up into the cable.

One of the most recent cables laid is that along the Persian Gulf, between Teheran and Bushire. The core of this consists of copper wire of good quality covered with Hooper's india-rubber compound to a diameter of ·320 inch. Two servings of hemp saturated with tar-water were then laid on in reverse directions, and strength was imparted by twelve galvanised wires ·192 inch diameter. These were separately covered with a mixture of tar and asphalte, and the whole then coated externally with two layers of Clark's Patent Asphalte Covering, so as to give it a smooth and even surface.


Fig. 12.

Fig. 12 shows a portion of the cable, each layer being separately removed to show the construction, while Fig. 13 shows a section. Many other forms of covering have been tried with varying degrees of success, the object in all being to reduce as far as possible the size, and consequently the weight of the cable. This, however, must not be done at the expense of strength or durability. One cable, constructed by Messrs. Siemens, consisted of a small core, protected in the usual way by fine hemp, and outside this four strips of thin copper sheet were wound round in such a way as partially to overlap one another. This cable, which was laid between Carthagena and Oran, worked uncommonly well for a little time, but it was laid on a very bad bottom, and consequently was soon chafed and broken. When the bed of the sea is rocky the cable is very apt to chafe, especially if there be any great inequalities. The best bottom is a flat one covered with fine sand or siliceous deposit. In this a cable is thoroughly protected, and should last almost indefinitely.

We have now carefully inquired into the different ways in which the electric fluid can be conveyed from place to place. It is, however, necessary, as we have seen in our lessons on "Electricity," to have a complete circuit in order for the current to produce any effects; in other words, we must provide some return path for the current, as well as a conductor along which it may travel to its destination. For this purpose a

special wire used to be erected, so that the current might pass along the one and return by the other. This was, however, soon found to be unnecessary, since the earth will answer every purpose of a return wire. All that is requisite is to bury a large plate of metal in the earth near each station, and let the earth wire of the distant station be connected with the one there, while one pole of the battery at the transmitting station is connected with its own earth plate. The current then passes along the wire, through the instrument, on to the earth plate, and back again by the earth plate to the battery, thus completing the circuit.

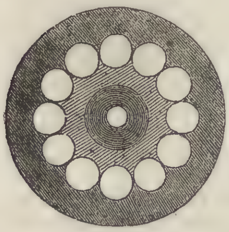


Fig. 13.

There are, however, a few occasions in which a return wire is a great advantage. Strong currents of electricity at times appear to travel from one part of the earth's surface to another. This is especially noticed during the appearance of the Aurora Borealis. Sometimes they continue to flow steadily in one direction, at other times they change very rapidly. These are known as "earth currents," and they seem to enter the wires by one of their earth connections and travel along them, deflecting the needles in their way. If the earth connections be severed, these currents at once cease in the wires; but while they are passing messages are considerably interfered with. Sometimes, when they are steady and uniform, communication may be maintained by cutting the batteries altogether out of circuit, and signalling by the earth current alone. It is not often, however, that this can be done, and the best course then, if there are several wires between the stations, is to alter the connections so as to make one a return wire, joining on the earth wires from the instruments to it instead of to the earth plate. When this is done the whole circuit is completely insulated and cut off from all communication with the earth; the earth currents cannot therefore pass along the wires, and if they affect the working at all, only do so by their inductive action.

Any line of telegraphs—whether aërial, subterranean, or submarine—is liable to injury, as, *e.g.*, by the breaking of an insulator or a wound in the insulating covering, and at first it was a somewhat difficult matter to discover the exact place of the fault, or, as it is termed, to "localise" it, the only plan being to test at intervals all along the line until the exact place at which the communication became defective was discovered. The rapid advance, however, made recently in the construction of delicate pieces of apparatus, and our increased knowledge as to the laws which regulate the passage of electric currents, now enable the operator, without leaving the station at which he is, to discover the exact place of the fault, and thus without loss of time to have it repaired. The manner in which this is accomplished we must explain in our next lesson.

ANIMAL COMMERCIAL PRODUCTS.—VIII.

HORNS AND ALLIED SUBSTANCES (*continued*).

HORN is manufactured into many other articles besides combs. Snuff-boxes, drinking-cups, shoe-horns, and powder-horns are all made of horn. The fragments of horn, melted and compressed into a solid mass in moulds, form bell-pulls, handles for table knives and forks, knobs for drawers, and many other useful articles; or, if exposed to a decomposing heat in close vessels, these fragments develop prussic acid, and for this reason are in demand among the manufacturers of Prussian blue, and of the beautiful yellow prussiate of potash. The solid tips of the horns are always sawn off, because these parts are not lamellated, and therefore incapable of separation into plates. They are made into knife and umbrella handles, the tops of whips, buttons, and various other articles both useful and ornamental.

The quantity of horn annually worked up in the manufactures of Great Britain, including the produce of our own animals, is estimated at 6,400 tons, of the value of £180,000. The comb manufacturers alone consume 1,300 tons, which produce £320,000 worth of combs. Horns of oxen are largely exported from South America, from Buenos Ayres, Monte Video, and Brazil, the last taking, as regards size and quality, the first rank. The Indian buffalo from Siam furnishes a very valuable horn, of which we receive annually about 26,000; the Cape of Good Hope and New South Wales also supply our markets with ox-horns. The manufacture of articles from hoofs and horns is carried on very extensively at Aberdeen in Scotland, where an immense establishment exists.

The hoofs of horses and ruminant animals, though similar to horn in character, are not so useful as horns, because they are much heavier and are less easily worked. They are, however, to some extent made available in the manufacture of buttons, cheap combs, and similar articles.

II. WHALEBONE.

Whale (*Balæna mysticetus*).—This animal furnishes the baleen, or whalebone of commerce. Commonly regarded as a fish, they are nevertheless true mammals, producing their young alive, and suckling them for a considerable time. They are very sociable, swimming in large shoals, and sporting on the surface of the water in their native Arctic seas.

Whalebone or baleen consists of numerous parallel laminæ descending perpendicularly from the palate of the animal. The object of this structure is to form an efficient sieve or strainer for the food of the whale, as it comes in with the water. Although provided with an immense mouth, this enormous creature has an œsophagus or food-pipe so small, that he is compelled to nourish his vast bulk by the consumption of some of the smallest inhabitants of the sea, his food consisting of small mollusca and crustacea. "To procure these insignificant morsels, he engulfs a whole shoal of them at once in his capacious jaws, where they are of course entangled among the fibres of the baleen; the water is then strained off and expelled through the blow-holes, and the monster is thus enabled to pass his diminutive prey at his leisure into his stomach."*

The length of the largest pieces of baleen in a whale sixty feet long is about twelve feet, and the pieces are arranged in two rows, 300 in each. The average weight of each piece is seven pounds, and the weight of the whole is therefore 4,200 pounds, or upwards of one ton and three quarters, worth about £160 a ton.

Whalebone is prepared for use by immersion for twelve hours in boiling water, which softens and renders it fit for manufacturing purposes. It is valued for its flexibility, tenacity, compactness, and lightness, and is cut into quadrangular sticks for the ribs of umbrellas and parasols, the supports of stays and other articles of ladies' wear. In thin strips whalebone is used for covering whip-handles, walking-sticks, and telescopes. These strips also are plaited like straw to form hats and bonnets, whilst the fine shavings are employed by the upholsterers as a stuffing for cushions, for filling fire-grates in summer, and for other useful purposes.

III. OSSEOUS SUBSTANCES.

Antlers.—The antlers of the different species of deer are very valuable for making a variety of useful and ornamental articles. The chief supply is furnished by the elk, wapiti, stag or red deer, and fallow deer. In Switzerland, brooches, pins, and bracelets are made from stag's horn; in Sheffield the whole shaft of the horn is used in making the handles of carving-knives, or it is cut up into small plates and riveted on to an iron case for the handles of pocket and pen knives. About 400 tons are annually imported from Hindostan and Ceylon for this purpose; another 100 tons come from Germany, Russia, Spain, and Italy, and from our own parks. About 18,000 head of deer are annually killed in Greenland, and their horns sent over to this country. The shavings of the horns are employed for the purpose of making ammonia, which has therefore long been popularly known as "hartshorn."

Ivory.—Our supplies of ivory are derived chiefly from the Asiatic and African elephants; the tusks or canine teeth of these animals furnish the article, but those of the African species are the most valuable. Elephants' tusks from two to ten feet in length, and weighing from 6 to 160 pounds, are imported into this country from Senegambia, Guinea, Mozambique, and Sofala; and also brought from the interior of Africa

* "Natural History of the Animal Kingdom." By W. S. Dallas, F.L.S. 1856.

in caravans and shipped at Alexandria, Tunis, Tripoli, and Cairo. We receive them, besides, from Bengal, Birmah, Siam, Cochin-China, Ceylon, Sumatra, and Java. There are large buildings erected in Birmingham for the manufacture of ivory, and also at Nuremberg in Germany. The Chinese are unrivalled in this manufacture. Their ivory balls, carved one inside another, are marvels of patience, industry, and ingenuity; and their chessmen, cabinets, drinking-cups, and numerous other articles made of this material are most elaborate in their ornamentation.

Generally and technically under the name of ivory are comprised the teeth of the narwhal (*Monodon monoceros*), walrus (*Trichecus rosmarus*), and hippopotamus (*Hippopotamus amphibius*), which, like ivory, are worked up into a variety of things, and always keep white.

Ivory is largely consumed in the manufacture of billiard-balls, which cost from six to twelve shillings each, and are so nicely turned that they are perfectly spherical, and made to correspond accurately in size and weight, even to a single grain. The greatest consumption of ivory is undoubtedly in connection with the cutlery trade. A large amount is also worked up in the manufacture of the backs and handles of the best hair and tooth brushes.

The miniature tablets, so invaluable to the artist, are cut from off the tusk by an extremely thin saw acting horizontally, just as we pare an apple; so that from a solid tusk, of the ordinary size, a sheet of very considerable length can be obtained. In the Great Exhibition of 1851, one manufacturer exhibited a sheet of ivory sixty feet in length, obtained without joining, and which had thus been pared off from a single tusk. We import annually 50,000 elephants' tusks, weighing 10,000 cwts., and consequently we may calculate that not less than 25,000 elephants are killed annually to supply the English market alone.

The material of ivory is so valuable, that economy in its use is necessarily studied, and the smallest fragments are preserved. The refuse of ivory is used for making the finest black colour (*noir d'ivoire*) by converting it into charcoal in air-tight vessels. Such ivory refuse, consisting of ivory scrapings, shavings, and sawdust, when boiled, makes an excellent jelly, quite as good as calf's-foot jelly, and with the advantage that it suffers no change by keeping. Ivory refuse is therefore saleable to the confectioner and pastrycook, by whom it is very frequently employed in this way.

Bone.—The skeleton, or framework of animal bodies consists of bones articulated with each other, which protect the vital organs, and form a basis or support for the softer parts, and for the attachment of the muscles, or organs of locomotion. In the arts, bones are extensively employed by the cutler, comb and brush maker, chemist, confectioner, and agriculturist. Common bone is manufactured into buttons, combs, knife, fork, and brush handles, card cases, parasol handles, book folders, and numerous other articles. The chemist obtains phosphorus, sal-ammoniac, and charcoal from bone, and the farmer a most valuable manure—super-phosphate of lime—which has a quick and efficient action on the crop. Large quantities of bones of oxen are imported to Great Britain from Buenos Ayres, etc., for this purpose; and also the bones of seals, captured in the North Seas for their fur and oil, and brought home by the sealers. The number of tons imported during the year 1867 amounted to 83,814.

TECHNICAL DRAWING.—XII.

DRAWING FOR JOINERS.

The limits of these lessons now render it necessary that some attention should be paid to such examples as form studies for drawing for joiners. Yet we would not wish to be understood that the lessons hitherto given do not appertain to joiners, or that those about to be given possess no value to carpenters. It is difficult to say what is the exact boundary which divides the two branches of wood-work. The general rule, however, is that carpenters' work is structural, and connected with the carcase, whilst that of a joiner comprehends the finishings of the outside and inside of a building. Of course, greater refinement and nicety is required by the joiner in practice; but this will not hurt the carpenter, nor can the structural knowledge required by the carpenter fail to benefit the joiner. In fact, a general knowledge of the practice of each will make both work with greater economy, for one will work into the other's hands; their work will, to use a technical term, "dovetail" together, therefore the two branches are not separated here by a hard line; and that the student may see that the higher branches of joinery approach cabinet-making and wood-carving, examples belonging to both of these branches are introduced. We all know the pleasure it is to meet with a joiner who, in addition to the work of laying down floors, putting up wainscots, or fixing window-sashes, can, when required, set out and execute a piece of Gothic panelling or an organ screen, or who is able to carve any portion of the turn of a moulding which cannot be worked with the plane or struck by the machine. We therefore strongly urge the student to work from the examples herein with the utmost care, and subsequently to follow up the system as he will find it laid down in the special technical lessons devoted to his trade.

Fig. 90 shows the method of uniting the boards *a* and *b* in a flat surface, called "dowelling." The edges of the boards having been accurately planed, holes are bored, pins (as at *e*) are glued into the one, and the projecting ends being inserted into corresponding holes in the edge of the other board, unite them firmly—the edge of the board *c* and the end of the pin being glued.

Square pieces of hard wood, or dowels, are often used in the place of pins, and are shown at *d*.

Fig. 91 is a method frequently adopted in floor-boards and panelling. It is called *rebating*, and consists in planing away half the thickness of the edge, so as to leave a ledge standing; all the boards being thus rebated, the ledge left on the one fills up the rebate, or "abated" edge of the other. This will be clearly understood on referring to the illustration.

Fig. 92 is a method of joining boards called "ploughed and tongued." In this case a groove is planed in the one edge, and a tongue left (by planing away the angles) at the other edge of each board; the tongue of the one then fits into the groove of the other. In very good work it is usual to plough *both* edges, and *insert* a separate tongue. This tongue is formed of strips cut the cross way of the wood, as shown in Fig. 93.

Fig. 94.—This method consists in working grooves across the back of the pieces, *a*, and forcing rabbets into them, as *b b*. The bottom of this groove is flat (A), and its sides slant inwards towards the bottom. The sides of the rabbet are also cut slantingly, and a joint is thus formed called the "dovetail notch."

This method is exceedingly well adapted for making drawing-boards. The rabbets must not then be glued, or otherwise fastened in, and thus, by means of their dovetailed edges, they keep the board from warping, whilst at the same time they allow of its expansion and contraction, and thus splitting and twisting are prevented.

Fig. 95 is an illustration of the method of clamping the ends of boards, *a b*, by tongueing the board and ploughing the piece which is to cross it, *c*. Sometimes, instead of bringing the end of the cross-piece flush with the edge of the board, it is cut off at an angle, the board being cut correspondingly to admit of the insertion. This last method is called *mitre clamping*.

Fig. 96 shows a very common method of joining up a flat surface by means of framing and panelling. A groove is run in the edge of the frame, the edges of the panel are rebated, and the whole brought up flush.

Fig. 97 shows a portion of a panel inserted into a frame where a flush surface is not required.

Fig. 98 represents one of the many methods employed for angle joints. It is the simple mortise and tenon, a shoulder being left on the outer side of the tenon by which the one piece is secured against being forced out of perpendicular.

Fig. 99 is another method, which is accomplished by means of a mitre, part of the wood being left as a tenon at the end of the one part, which is inserted into the mortise at the end of the other. A pin is then passed through the whole.

DOORS.

The most common kinds of doors are constructed of several simple boards, not fixed with glue or any tenacious substance, but by nailing transverse pieces upon the back of the boards

laid edge to edge. The transverse pieces thus nailed are called *ledges* or bars, whence the door is said to be ledged or barred. In this case one of the edges at every joint is beaded on both sides, or at least on the face which is outside, the edges being placed on the inside.

Doors of this description are generally employed in cottages or out-houses.

Where doors are required to combine strength, beauty, and durability, a frame, joined with mortise and tenon, must be constructed, with one or more intermediate openings, each of which must be surrounded by three or more parts of the frame, which have grooves ploughed in the edges for the reception of boards to close the openings, inserted as in Fig. 97.

The parts of the framing which are horizontal when the door is hung or fixed upon its hinges are called *rails*—upper, middle, and lower. The extreme parts of the frame, to which the rails are fixed, are called the *stiles*, and the intermediate ones are termed *mountings*. The boards by which the interstices are closed are called *panels*.

Fig. 100 is the elevation of a pair of folding - doors, with mouldings and cornice. In this example it is desirable to commence by drawing the entire framing and cornice, with their mouldings. Then draw a central perpendicular, on which mark off the heights of the various rails and panels, and draw horizontal lines for the upper and lower edges of these. From the central perpendicular next set off the width of the stiles, etc., and draw the necessary perpendiculars. The mouldings to the panels may now be added.


Fig. 100

Fig. 101 is the section, on a larger scale, of the frieze and cornice, showing how the various members are put together. The ornamental moulding, *f*, is in this design supposed to be made of pressed zinc, in which some very beautiful patterns are now worked, which are by far more durable than those made of composition.

Fig. 102 shows the manner in which such doors meet in the middle.

Fig. 103 is the plan of a folding (or French) window and shutter-box. *a* is the framing of the window; *b*, the window; *c d*, the folding shutter closed; *c d*, ditto folded; *e f i*, the casing of the shutter-box; *g*, the wall; *h*, the inner casing.

PARQUET WORK.

Parquetry is a beautiful species of flooring, consisting of various patterns formed of different woods—such as cherry, oak, ebony, walnut, mahogany, maple, etc. It is very much used both in Germany and France, and is now becoming fashionable in England. The wood of which the parquetry consists is usually one inch thick, grooved, tongued, and keyed at the back and corners. It is well adapted for reception rooms and picture galleries, for borders round Turkey carpets, as well as for landings and panelling of rooms.

Fig. 104 is a design based on the square only, and is too simple to require any instructions as to drawing, further than the advice already so frequently given — to work with the utmost accuracy, for in such repeating patterns, any one of the component figures, being inaccurately formed, throws out the whole design.

Fig. 105. — This design is drawn by setting out a number of squares. Draw diagonals and circles from the angles. All the other lines employed will be found to be parallel to these.

Fig. 106 is also based on the square. Having set out a number of squares, divide the sides of each into three equal parts, and draw lines across so as to divide each of the squares into nine smaller ones. In each of the four small squares occupying the corners of the larger ones, draw one diagonal; and in each of the four squares occupying the middle of the sides draw two diagonals. By shading the portions as in the example, the design will be developed.

Fig. 107 is based upon the hexagon. To draw this pattern, construct a line of regular hexagons, each touching two others by their angles; divide each hexagon into six equilateral triangles by diagonals. Find the middle of the sides, and draw lines to the middle points of the alternate sides; these will give two equilateral triangles crossing each other; and the required portions being coloured, the star in the centre will be left. The darker lines are drawn parallel to the sides of the hexagon.

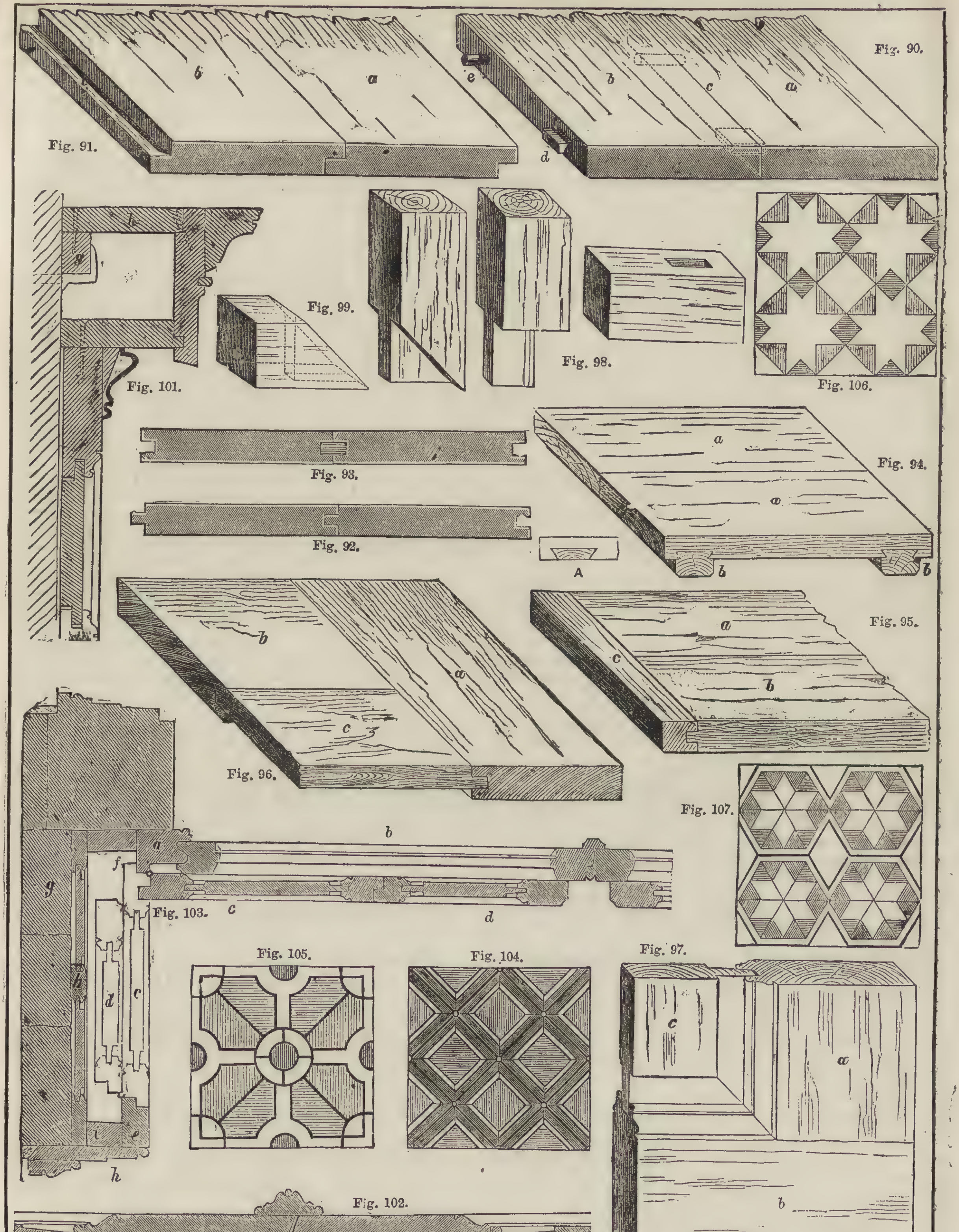


Fig. 90.
Fig. 91.
Fig. 99.
Fig. 98.
Fig. 106.
Fig. 101.
Fig. 93.
Fig. 94.
Fig. 92.
A
Fig. 95.
Fig. 96.
Fig. 107.
Fig. 103.
Fig. 105.
Fig. 104.
Fig. 97.
Fig. 102.

VEGETABLE COMMERCIAL PRODUCTS.—VI.

PLANTS USED IN THE PREPARATION OF NUTRITIOUS AND STIMULATING BEVERAGES (*continued*).

PARAGUAY TEA, OR MATÉ (*Ilex Paraguayensis;* natural order, *Aquifoliaceæ*).—A small shrub with oval, wedge-form, or oblong-lanceolate, toothed, smooth leaves, somewhat like those of the orange. This plant, which is, in fact, a species of holly, occupies the same important position in the domestic economy of South America that the Chinese plant does in this country. The leaves are prepared by drying and roasting—not in the manner of the Chinese teas, in which each leaf is gathered separately; but small branches with the leaves attached to them are cut from the plant, placed on hurdles over a wood fire, roasted, and then beaten on a hard floor with sticks. The dried leaves and stems thus knocked off are collected, reduced to powder, and packed in hide sacks. Each of these sacks, when full, contains from 200 to 250 pounds of the tea. The sacks are sewed up, and as the hide dries and tightens by exposure to the sun over its contents, at the end of a couple of days the tea forms a substance as hard as stone, and almost as heavy.

As found in commerce, Paraguay tea is, therefore, in the form of a greenish-yellow powder, mixed with broken leaves and stems. This is infused in boiling water, and the decoction is drunk, or rather sucked up, by means of a tube perforated with small holes. It is usually imbibed out of a small gourd or cup with a little sugar, and sometimes an aromatic is added, such as orange or lemon-peel, or cinnamon, to give it an additional flavour. Maté is generally disagreeable to those unaccustomed to its use, but a taste for it is soon acquired, and it is very refreshing and acts as a restorative to the human frame after great fatigue.

It has been calculated that 40,000,000 pounds of Paraguay tea are annually consumed in the various South American Republics.

COFFEE TREE (*Coffea Arabica*, L.; natural order, *Rubiaceæ;* sub-order, *Cinchonaceæ*).—An evergreen shrub, from fifteen to twenty feet in height, with an erect stem covered with a brownish bark, and opposite branches with a slightly downward inclination, giving to the whole shrub an elegantly beautiful pyramidal contour or outline. Leaves opposite, short-stalked, ovate-lanceolate, entire, glossy dark-green above, paler beneath, and from two to three inches long; flowers, white and funnel-shaped; fruit, a globular two-celled and two-seeded berry, about the size of a cherry. The seeds, freed from their hard, horny, parchment-like husk, are hemispherical, with one side convex, and the other flat and furrowed.

The flowers of the coffee-tree resemble those of the white jessamine, and appear in clusters in the axils of the leaves. The trees are very beautiful and fragrant when in bloom, and not less attractive when the berries are ripe and ready for cropping, for these are then of a deep scarlet colour, and show to great advantage amongst the dark-green glossy leaves.

The home of the coffee-tree is said to be Abyssinia, where it still grows wild; thence it was transplanted to Arabia towards the close of the fifteenth century. It was introduced by the Dutch into Batavia in 1690, and thence carried to the West Indies in the beginning of the eighteenth century, and afterwards to the Brazils. Coffee is now grown in almost every tropical country having an average temperature of above 55°. We receive it from Java in the East Indies, from Trinidad in the West Indies, and from Rio Janeiro in South America. The best coffee comes from Mocha in Yemen, the southernmost province of Arabia.

As soon as the crimson colour of the coffee berry indicates the time for harvesting, the berries, which drop readily when mature, are shaken from the trees upon cloths or mats spread under them. They are then piled together in heaps for forty-eight hours to soften the pulp, and afterwards put into tanks through which water flows continually, to wash off the pulp; the berries are then spread out on the platform, with which every coffee estate is furnished, to dry in the sun. But there still exists the husk, which is broken off by means of heavy rollers; the seeds are then winnowed, and put into bags for sale.

Raw coffee is roasted, after it arrives in this country, in a hollow iron cylinder, which is kept turning for half an hour over a charcoal fire until the berries are coloured sufficiently brown. Roasting coffee improves its flavour and power as a stimulant.

Coffee owes its properties to a peculiar principle, which has been called by chemists caffeine, and which is identical both with the theine of the tea and the theobromine of the cocoa plant. It is worthy of note that the common beverages of man—tea, coffee, and cocoa—although found in the most dissimilar plants, nevertheless contain identically the same peculiar principle which gives them their nutritious and stimulating properties.

Coffee is said to have been first used by the Persians as a beverage as early as 875 A.D., and from them the Arabs learned its value. The first Arab who drank coffee was Megalledin, Mufti of Aden, in Arabia Felix, who had become acquainted with this use of the coffee berry when in Persia. The consumption of coffee was not at all rapid at first, and it was not until 1554 that it was publicly sold at Constantinople. It afterwards became very popular with the Turks, but as it frequently led to social and festive meetings, which were considered incompatible with the strictness of Mahometan discipline, its use was restricted by the Turkish Government, though without effect. In vain the Turkish priests complained to the authorities that the mosques were deserted, whilst the coffee-houses were crowded; in vain the latter were shut up by order of the Mufti, and the police employed to prevent any one from drinking coffee; the Turks found means to elude their vigilance. They would have their coffee. The law, therefore, became only a dead letter, and although never repealed, the Government acknowledged its defeat by finally laying a tax on the beverage, thus making it a source of considerable revenue.

The consumption of coffee in Turkey is very great. This is probably owing to the strict prohibition which the Moslem religion lays against wine and spirituous liquors. So necessary is coffee to the Turks, that the refusal of it in reasonable quantities to a wife is considered to be a sufficient ground for a divorce. The coffee-houses in Turkey are very numerous, and some of them spacious and handsome. In Constantinople, such as are regularly licensed are gaudily painted, and furnished with mats, platforms, and benches. Sometimes there is a fountain in the middle of the room, which renders the atmosphere delightfully cool; and also a gallery for the musicians. Towards evening these houses become thronged with a motley assemblage of Armenians, Greeks, and Jews, all smoking and indulging in tiny cups of coffee, generally drunk without either sugar or milk.

It is in the Turkish coffee-houses that the vagrant story-teller finds his stage and his audience. He walks to and fro, stopping when the sense of his story requires some emphatic expression or attitude, and generally contrives to break off in the most interesting part of his tale, making his escape from the room despite every precaution that may be taken to prevent him. His auditors thus compelled to restrain their curiosity, are induced to return at the same hour to the coffee-room. As soon as he has made his exit, the company present commence an animated discussion, in separate parties, as to the character of the drama, and the principal events of the story.

The following account, by Mr. M'Farlane, is characteristic of Turkish manners, and of the mode in Turkey of setting aside the laws in reference to coffee:—

"I was surprised to see in Smyrna, and in numerous other towns, the scarcity of coffee-houses and the quantity of barbers' shops. It was explained when, on wishing to rest a while, my servant David led me into one of them, which in appearance was devoted to shaving, but which concealed behind a wooden screen, that looked like the end of a room, a spacious recess hung with *chibouks*, or common pipes, *narghiles*, or water pipes, and tiny coffee-cups. The small characteristic fire for the preparation of the fragrant berry was burning in the usual corner, and there were the usual supplies of benches and stools—in short, it was a *bonâ fide* coffee-house, screened by a barber's shop, and a group of Osmanlis shuffled in after us, not to be shaved, but to smoke their pipes and drink their cup of coffee.

"'David,' said I, 'are all these hundreds of barbers' shops nothing but veils for coffee-houses?'

"'Not all, but the greater part of them,' was the answer.

"'Yet the disguise may be easily penetrated. Any bostangi might discover the recess, and arrest a crowd of delinquents, as here, for example.'

"'That is all very true,' said David, 'but what would the bostangi get by that? The fact is, the Turks cannot live

without coffee-houses; besides, the order to shut them up is now an old affair. Each proprietor may make it worth his while not to see, and so you understand the bostangi and his officers need not look beyond the barber's shop.'

"During the latter part of this speech, a Mollah, a stout advocate of both law and gospel, stepped in, and called for his narghile and coffee!"

Coffee was first sold in London in 1652, by a Turkish merchant, who kept a house for that purpose in George Yard, Lombard Street. It soon became very popular, and in 1660 a tax of fourpence on the gallon was levied on all coffee made and sold. It spread amongst the English for reasons very similar to those which caused its spread among the Turks. According to Macaulay,* it extended most rapidly. To be able to spend the evening sociably at a small charge soon become fashionable. The coffee-house was "the Londoner's home." Nobody was excluded who laid down his penny at the bar. There were coffee-houses where politics were discussed, where literary men held their meetings, and where doctors, divines, and lawyers congregated, and might be consulted. "There were Puritan coffee-houses, where no oaths were ever heard, and where lank-haired men discussed election and reprobation through their noses; Popish coffee-houses, where good Protestants believed over their cups that the Jesuits were planning another Gunpowder Plot, and casting silver bullets, to shoot the king; and Jew coffee-houses, where the money-changers of different nations greeted each other." Such was the respectable position of a London coffee-house in 1685. Lloyd's was originally a coffee-house at which insurers and underwriters met. These houses have long ceased to be the favourite haunts of literary men and fashion, and, although still retaining their ancient name, they are now on a level with an ordinary restaurant, having been superseded as places of entertainment by the numerous music-halls and club-rooms in the metropolis, where something more stimulating than coffee is usually in demand.

Coffee, like tea, is frequently adulterated. Of these adulterations the most common one is chicory (*Cichorium intybus*, L.), a plant resembling a dandelion, with blue flowers, belonging to the natural order *Compositæ*. The large tap-roots of this plant are sliced and dried in kilns; they are then roasted and reduced to powder, and this, when boiled, yields a drink not unlike coffee. Chicory is perfectly wholesome, containing no alkaloid or oil, and only a small amount of narcotic matter. When added to coffee in small quantities, it rather improves its flavour, neutralises its oil, and renders it less difficult of digestion. The sale of chicory is now legalised. Many persons prefer the coffee with chicory.

The adulteration of coffee with chicory is easily detected. Roasted coffee imparts its colour very slightly to cold water, but chicory colours the water a deep-reddish brown. Coffee is light, and floats on the surface of the water; chicory is heavy, and sinks to the bottom.

The best coffee, called Mocha coffee, comes from Yemen in Southern Arabia; Loheia and Mocha are the principal ports for its exportation on the Red Sea, besides which, Aden, acquired by England in 1838, will soon become an important coffee mart. About 4,000 tons of this coffee are annually exported. East Indian coffee ranks next in commerce, chiefly the coffees of Ceylon and Batavia. About 50,000 tons of East Indian coffee are annually produced. An inferior kind, called green coffee, is raised in the West Indies—in Jamaica, Cuba, St. Domingo, Trinidad, Guadaloupe, Porto-Rico, and Martinique—to an annual amount of about 70,000 tons. Other American coffees also come from the free States of Venezuela and New Granada, from the Brazils, Cayenne, and Surinam. The annual produce of coffee in South America may be estimated at 81,000 tons. In 1867 about 61,486 tons were imported into the United Kingdom, principally from our foreign possessions. We export coffee also largely to our colonies and Australia. Hamburg and Amsterdam are the most important coffee markets, and next to these London, Rotterdam, Antwerp, Havre, and Trieste.

COCOA (*Theobroma cacao*, L.; natural order, *Byttneriaceæ*).—A tree, about twenty feet in height, with dark-green leaves, from four to six inches in length and about three inches in breadth, elliptical, oblong, and pointed, the margin entire, and slightly wavy; the flowers are small and white, growing directly both from the stem and branches; the fruit somewhat resembles a cucumber; it is about five inches in length, and three inches and a half in diameter, at first green, but when ripe, yellow. Within this fruit, embedded in the pulp, are from forty to fifty cocoa-beans or seeds, packed closely together in five rows, around a common centre.

The cocoa-trees will only grow well in the shade. They are planted at intervals of twelve feet apart, and are protected from the fierce heat of the tropical sun by the broad-leaved banana and the stately and beautiful *Erythrina*, or coral-tree. The rays of the sun cannot penetrate the foliage of these trees, and the ground below them is constantly wet. When the fruit is ripe, it is plucked and opened; and the beans, cleared of the spongy pulp, are spread upon mats to dry in the sun.

Chocolate and cocoa are both made from these beans. Chocolate is made by first freeing the beans from their husk, and then roasting them over a fire in an iron cylinder, with holes in its end for the escape of the vapour. The apparatus is very similar to that of a coffee-roaster. When the aroma is well developed, the beans are roasted; they are then turned out of the cylinder, and ground to a powder, which, mixed with sugar, flavoured with vanilla, and brought to a paste, forms the chocolate cakes of commerce. Cocoa is prepared by grinding up the entire nut—both husk and kernel—after roasting, a quantity of suet being added during the process of grinding. Sometimes the beans are roasted and simply crushed. This preparation is sold in the shops under the name of *cocoa nibs*.

The cocoa-tree is a native of South America, Mexico, and the West Indies, where it formerly grew wild, but is now cultivated in extensive plantations. The beans of this tree have always been the chief means of nourishment of the natives of those countries. From them the Spaniards learnt to make both chocolate and cocoa.

The cocoa bean, which is about the size and colour of an almond, contains a peculiar solid oil called *butter of cocoa*, and an alkaloid called *theobromine*, which produces on the nervous system analogous effects to those of *caffeine* and *theine*. Chocolate and cocoa yield highly nutritious beverages. Linnæus was so convinced of this, that he called the plant *Theobroma*.

Cocoa is imported into this country chiefly in the raw state, that is, the beans with the husks on. The following are the principal sorts which are brought into Europe. The preparation, Chocolat Menier, is from cacao grown in the district of Rivas, Nicaragua. Soconusco, the best sort, comes from the district of the same name in the free state of Guatemala. This seldom comes into the market. Caracas, the next in quality, comes from La Guayra, the commercial port of Caracas in Venezuela, also from Guayaquil in Ecuador. Our largest supplies come from these ports. We receive also heavy shipments from English, Dutch, and French Guiana, Brazil, Mexico, and the West Indies, especially from the island of Trinidad.

In 1867, 11,954,862 lb. of cocoa were imported into the United Kingdom. Its consumption in France, Spain, and Portugal is continually increasing. Chocolate is more used in France and Spain than in England. It forms the ordinary breakfast of the Mexicans.

Both chocolate and cocoa are much adulterated with wheaten and potato flour.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—III.

IT is now intended to show the construction of Gothic tracery. Some of the figures used in the designs of windows, etc., in churches of the Middle Ages are extremely beautiful; yet all the forms grow out of others of the most simple character, dependent on correct geometrical construction. The quatrefoil, which forms the subject of the present lesson, is based upon a square drawn on given diagonals; and this elementary figure, and one of a similar character, are therefore given as steps in the construction.

To construct a square on a given diagonal, A B (Fig. 24).

Bisect the diagonal A B in the point C. From C, with radius C A, describe a circle cutting the bisecting line in D and E. Draw A D, D B, B E, E A, which will complete the square on the given diagonal A B.

To construct a parallelogram when the diagonal A B *and the length of one pair of sides* C *are given* (Fig. 25).

* "History of England, from the Accession of James II.," by Lord Macaulay, Vol. I., p.175.—People's Edition, 1864.

Bisect A B in the point O. From O, with radius O A, describe a circle. From A and B set off the length of the line C on the circle—viz., A D and B E. Join these points, and the required figure will be completed.

*To construct a Gothic quatrefoil** (Fig. 26).

Construct a square on the diagonal A B (see Fig. 24). Bisect the sides by the lines E G, F H, cutting the lines A C, C B, B D, and D A, in *i*, *j*, *k*, *l*. From A, C, B, and D, with radius A *i*—that is, half the side of the square—draw the arcs *l′*, *m*, *n*, *o*, and those concentric with them. The outer circles are drawn from the centre O.

To inscribe a square in any triangle, A B C (Fig. 27).

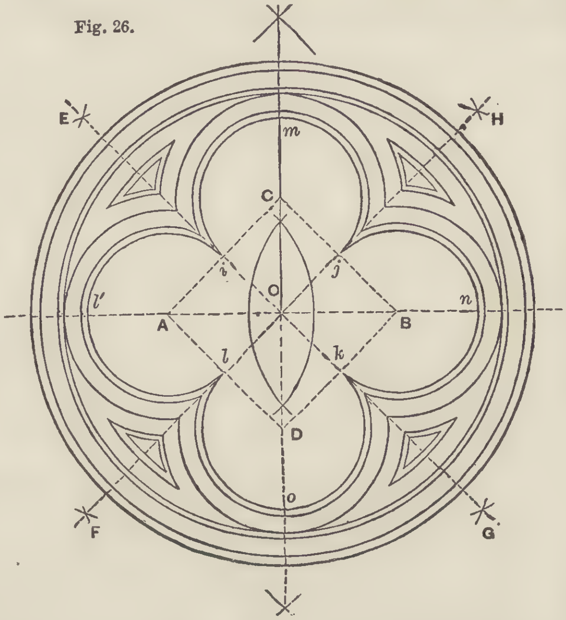
From C drop a perpendicular, C D. From C draw a line parallel to A B—viz., C E. From C, with radius C D, describe a quadrant cutting C E in F. Draw F A, cutting C B in G. From G draw G H parallel to A B. And from G and H draw lines G I and H J parallel to C D, which will complete the square in the triangle.

To inscribe a square in a given trapezium, A B C D (Fig. 28).

Draw the diagonals A C and B D. Draw D E at right angles and equal to D B. Draw E A, cutting C D in F. Draw F G parallel to A C. Draw G H and F I parallel to D B. Join H I, which will complete the square in the trapezium.

To inscribe a circle in a given trapezium, A B C D, *of which the adjacent sides are equal* (Fig. 29).

Fig. 26.



To trisect a right angle*, A B C (Fig. 30).

From B, with any radius, describe the quadrant D E. From D, with the radius D B, describe an arc cutting E D in F. From E, with the same radius, describe an arc cutting E D in G. Draw lines B F and B G, which will trisect right angle.

THE MEASUREMENT OF ANGLES (Fig. 31).

Angles are estimated according to the position which the two lines of which they are formed occupy as radii of a circle.

The circle being divided into 360 equal parts, called "degrees," it will be evident that the lines A O C contain 90 degrees (written 90°), or a right angle. Similarly, B O C is a right angle.

Now, if these right angles be trisected (as per last problem), each of the divisions will contain 30°, thus:—

A O E	is an angle	of	30°
A O F	,,	,,	60°
A O C	,,	,,	90°
A O G	,,	,,	120°
A O H	,,	,,	150°

A O B is in reality not any angle at all, being a perfectly straight line; but the slightest divergence from it would cause it to become an angle; as 179°, etc.

Each of these angles being again divided into three parts will give tens, which may again be divided into units; and thus angles may be constructed or measured with the greatest accuracy.

Fig. 24.

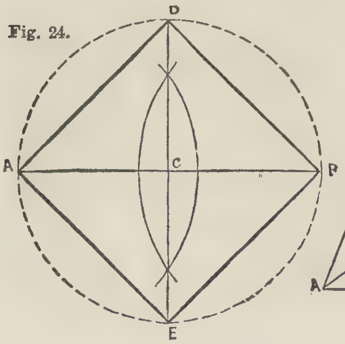


Fig. 27.

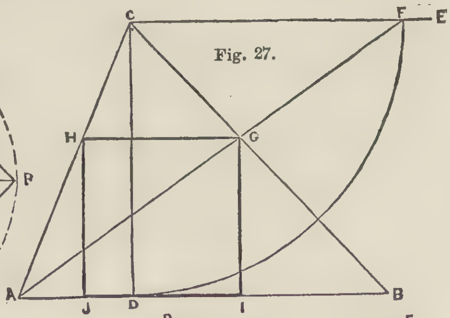
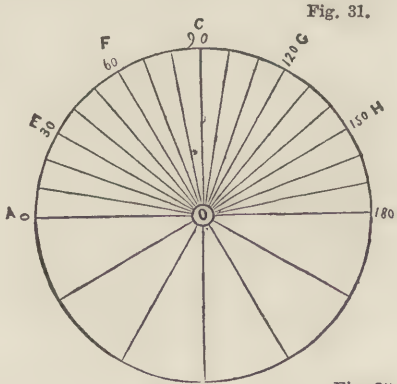


Fig. 31.



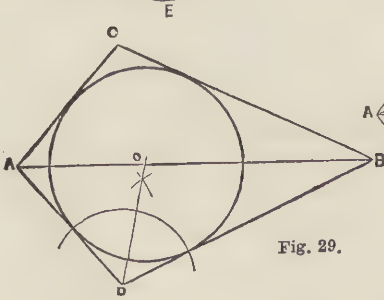


Fig. 29.

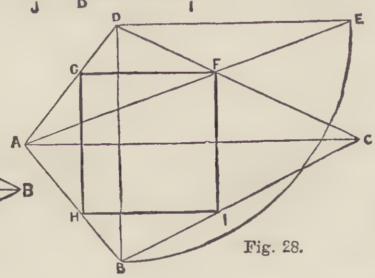


Fig. 28.

Fig. 30.

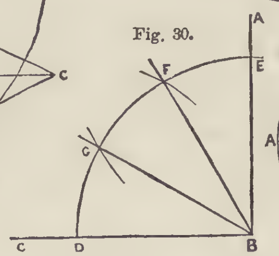
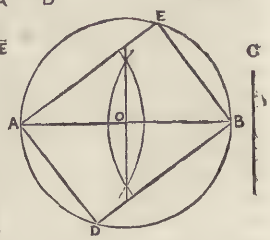


Fig. 25.



Draw the diagonal A B, which will bisect the angles C B D and C A D. Bisect the angle A D B. Produce the bisecting line until it cuts A B in O. Then O is the centre from which a circle may be described, touching all four sides of the trapezium.

Example No. 1 *of the foregoing* (Fig. 32).—To find the angle contained by the lines A B C.

Erect a perpendicular at B. Draw the quadrant D E, and trisect it. Divide the arc G E into three equal parts by points H and I (70° and 80°). Bisect the arc H I, and it will be seen

* The *Quatrefoil* is a figure based on four leaves or lobes. See remarks on the Trefoil (Fig. 11).

* *Trisect.* To cut into three equal parts.

that the line B C falls precisely on the bisecting point. A B C is therefore an angle of 75°. Had the line B C not fallen exactly in the bisecting point, further subdivision would have been necessary.

Example No. 2 (Fig. 33).—To construct at a given point B an angle of a required number of degrees, say 100°.

At B erect a perpendicular, B C. Trisect the right angle, carrying on the arc beyond the perpendicular, C. Divide any one of the three divisions into three equal parts representing tens. Set off one of these tens beyond C, viz., to D. Draw B D. Then A B D will be an angle of 100°.

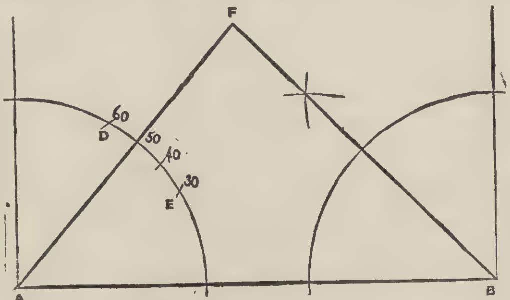


Fig. 34.

To construct a triangle, when the length of the base and the angles at the base are given (Fig. 34).—Let it be required that the base should be 2·5 (2, *decimal* 5, *or* 2 *and* 5 *tenths, which is* $2\frac{1}{2}$) inches long, that the angle at A should be 50°, and that at B 45°.

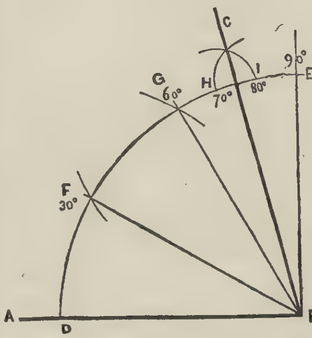


Fig. 32.

Draw the base 2·5 inches long. At A erect a perpendicular; draw a quadrant and trisect it in E D. Divide the middle portion, D E, into three equal parts, and the second division from E will be 50°. Draw a line from A through point 50, and produce it. At B erect a perpendicular, and bisect the right angle thus formed (as 45° is one-half of 90°). Produce the bisecting line until it meets the line of the opposite angle in F. Then A B F will be the required triangle.

Note.—All the three angles of a triangle are always equal to two right angles, that is, 180°; and therefore, as one of the above angles is 50°, and the other 45°—total 95°—the vertical angle, that is, that opposite the base, will be 85°.

THE PROTRACTOR (Fig. 35).

For measuring and constructing angles, there is in most cases of mathematical instruments a brass semicircle called a *protractor*. This has already been referred to, and is here given to show its practical application. This has a short line marked at C, and two rows of figures round the rim—the one reading from right to left, and the other the reverse way.

In order to measure an angle by means of the protractor, place the edge A B on the straight line which is to form one of the sides of the angle, with the point C exactly against the point of the angle to be measured. Then the line C D will be seen to correspond with the point 60°, and B C D is therefore an angle of 60°; or, reading from the left side, A C D is an angle of 120°.

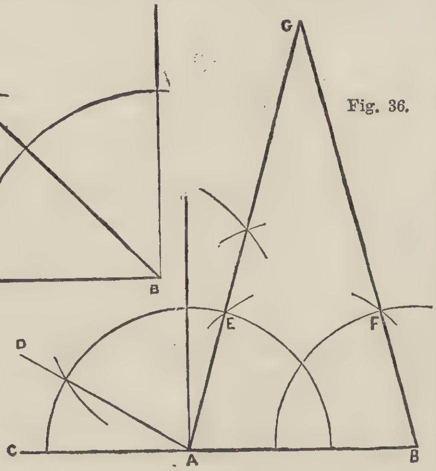


Fig. 36.

In constructing an angle, place C against the point at which it is desired to construct an angle; mark a point on your paper exactly against the figure corresponding to the number of degrees required; remove the protractor, and draw a line through the point thus obtained, to C, which will give the desired angle.

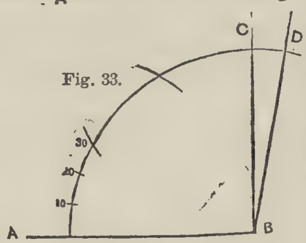


Fig. 33.

Protractors are sometimes made of wood or ivory, and of a rectangular form, as E F. These are used in a manner similar to the semicircular instruments, but are not generally thought as useful or exact in practice.

To construct an isosceles triangle on a given base, and having a given vertical angle (say 30°). (Fig. 36.)

Before commencing to work this figure, it is desirable that attention should be called to the principle upon which the construction is based.

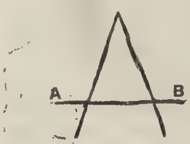


Fig. 39.

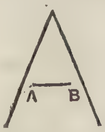


Fig. 38.

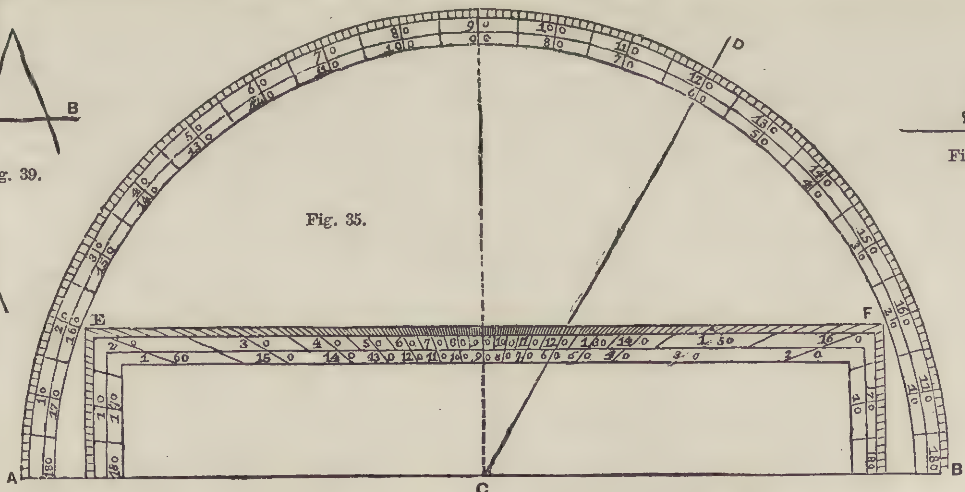


Fig. 35.

Fig. 37.

It has been shown that all the angles of a triangle, of whatever shape it may be, will always be equal to two right angles (viz., 180°).

Every straight line then is equal to the bases of two right angles; for a perpendicular drawn at any point will at once form two right angles, equal to 180°, upon it (Fig. 37).

Now let it be supposed that £180 are to be divided between

three persons, *that one of them is to receive* £30, and the remainder to be equally divided by the other two.

It will be seen at once that, when the first condition has been fulfilled, and £30 deducted from £180, the remainder will be £150, or £75 for each of the remaining claimants.

It is on a similar principle that this operation is based; and this mode of procedure is rendered necessary because we cannot *commence* by constructing the vertical angle; for, as the base A B is fixed, we should not know *where* to commence the vertical angle, so that the sides might not cut through A B (Fig. 38), or pass beyond it (Fig. 39); and thus we are compelled to construct the angles at the base firstly, and of such a number of degrees, that they should meet in the required angle.

Now it has been shown that 180° stand on every line.

Returning now to Fig. 36, produce A B, and at A construct an angle of 30°—viz., C A D.

So that out of the whole sum of 180° we have set aside 30°, the fixed number.

Bisect the remaining angle D A B in E. Draw A E. At B construct an angle A B F, similar to the angle B A E.

Produce lines A E and B F, which will meet in G, and will form the required angle of 30°.

NOTABLE INVENTIONS AND INVENTORS.

IV.—CLOCKS AND WATCHES (*continued*).

BY JOHN TIMBS.

THE middle of the fourteenth century seems to be the time which affords the first certain evidence of the existence of what would now be called a clock, or regulated horological machine; for although the term "horologia" had been of frequent occurrence in preceding ages, there is every reason to believe it was applied to other horological instruments. It appears from a letter written by Ambrosius Camalodunensis to Nicolaus of Florence, that clocks were not very uncommon in private families on the Continent about the end of the fifteenth century, and there is good reason for supposing that they began to become general in England about the same period; for we find in Chaucer, who was born in 1328 and died about 1400, the following lines:—

> "Full sickerer was his crowing in his loge,
> As is a clock, or an abbey orloge."

It is also believed, on good grounds, that a clock is not the invention of one man, but a compound of successive inventions, each worthy of a separate contriver. Thus, (1) wheelwork was known and applied in the time of Archimedes. (2) A weight being applied as a maintaining power would, in all probability, have at first a fly similar to that of a kitchen-jack, to regulate the velocity. (3) The ratchet-wheel and click for winding up the weight, without detaching the teeth or main wheel from those of the pinion in which they were engaged, would soon be found an indispensable contrivance. (4) The regulation by a fly, being subject to such great changes from the variations of density in the atmosphere, and the tendency of a falling body to accelerate its motion, would necessarily give rise to the alternate motion of the balance, with which invention an escapement of some kind must have been coupled. (5) The last-mentioned two inventions are most important ones, and would have induced such a degree of equability in the motion of the whole work, as would lead the way to a dial-plate, and to its necessary adjunct—a hand or pointer. Lastly, the striking part, to proclaim at a distance, without the aid of a person to *watch*, the hour that was indicated, completed the invention. And the supposition, that De Wyck's clock was a combination of the successive inventions of different individuals, is confirmed by analogy; for the clocks and watches of the present day have been brought to their present degree of perfection by a series of successive inventions and improvements upon what may now be called the rude clock of De Wyck, which is the most ancient clock of which we have a description. This—and, indeed, all clocks made with a balance for a regulator, without any regulating spring—must have been very imperfect machines; yet as early as 1484 a balance clock was used for celestial observations, and was superseded by the use of a portable one for ascertaining the longitude at sea, about 1530. Ancient clocks must have been reduced to a portable size prior to 1544, when the mainspring was substituted for the weight as a moving power; and this may be considered a second era in horology, from which may be dated the application of the fusee, round which is wound the chain or cord.

Among the earliest of the wheel-clocks seen in England was that of St. Paul's Cathedral, London, in 1286; and an agreement of 1344 shows that iron and steel were then used for the frame and clock, as they were until towards the end of the sixteenth century. The present clock at St. Paul's is remarkable for the magnitude of its wheels and the fineness of its works; it was made by Langley Bradley, at a cost of £300. It has two dial-plates, each between 50 and 60 feet in circumference; the hour numerals are a little over 2 feet in height; the minute-hands, 8 or 9 feet long, weigh 75 pounds each, and the hour-hands, between 5 and 6 feet long, weigh 44 pounds each. The pendulum is 16 feet long, and its bob weighs 180 pounds, but it is suspended by a spring no thicker than a shilling. Its beat is 2 seconds—that is, a dead beat, of 30 to a minute, instead of 60. The clock, going 8 days, strikes the hour on the brim of the great bell with a hammer; its head weighs 145 pounds, and is drawn by a wire to the back part of the clockwork, falling by its own weight on the bell, it can be heard at a distance of 22 miles; the clapper weighs 180 pounds; diameter of bell, 10 feet; weight, 102 cwt. Below this bell are the two quarter bells.

The Horse Guards' clock, we may here mention, made in 1756, was originally of coarse work. It was repaired and improved in 1815, and measures time sufficiently accurate for practical purposes, not connected with astronomical observations; but much of its reputation is conventional, from its association with "military time" of the Horse Guards.

Clocks remained with balances for the motive power until the middle of the seventeenth century, when the pendulum was first applied—it is said by Galileo observing the oscillations of a lamp suspended in the cathedral at Pisa. The discovery is also claimed for Huygens, Bergen, Hooke, and others, about the same time; but the "ancient astronomers of the East employed pendulums in measuring the times of their observations, patiently counting their vibrations during the phases of an eclipse, or the transit of the stars, and renewing them by a little pressure of the finger when they languished; and Gassendi, Riccioli, and others, in more recent times, followed their example." ("Encyclopædia Britannica," 8th edit.)

"Clocks and watches," says Mr. Babbage, "may be considered as instruments for registering the number of vibrations formed by a pendulum or a balance. George Graham, in 1715, first applied a compensating power to counteract the effect of heat and cold upon the length of the pendulum; and John Harrison, in 1726, used different metals to compensate each other, the rods being placed in the form of a gridiron. The mechanism by which these numbers are counted is technically called a scapement. A common clock is merely a pendulum, with wheelwork attached to it to record the number of the vibrations; and with a weight, or spring, having force enough to counteract the retarding effects of friction and the resistance of the air. The wheels show how many swings or beats of the pendulum have taken place, because at every beat a tooth of the last wheel is allowed to pass. Now, if the wheel has sixty teeth (as is common), it will just turn round once for sixty beats of the pendulum, or seconds; and a hand fixed on its axis, projecting through the dial-plate, will be the second-hand of the clock. The other wheels are so connected with the first, and the number of the teeth on them so proportioned, that one turns sixty times slower than the first, to fit its axis to carry a minute-hand; and another, by moving twelve times slower still, is fitted to carry an hour-hand."

A few public clocks may be noted here. The Bank of England clock, in the roof, is a marvel of mechanism, as it is connected with all the clocks in the Stock Offices. The hands of the several dials indicate precisely the same hour and second, by means of connecting brass rods (700 feet long, and weighing 6 cwt.), and 200 wheels; the principal weight being about 300 lb. The General Post Office clock, by Vulliamy, is a beautiful work of art on a small scale; its pendulum-bob weighs 448 lb., and requires only 33 lb. to cause it to vibrate 2′ 20″ on each side of zero—an extremely small motive power. The clock of the Royal Exchange, manufactured by Dent in 1843, has been pronounced by the Astronomer Royal as "the best public clock in the world;" the pendulum, weighing nearly

4 cwt., is compensated, the first stroke of the hour is true to a second, and it can also be set to any fraction of a second. This was the first turret clock constructed by Mr. Dent. The Westminster Palace clock, designed by Mr. Denison, and made by Mr. Dent, jun., about 1855, has four dials, each 22 feet in diameter—the largest in the world with a minute-hand; the great wheel of the going part is 27 inches diameter; the pendulum is 15 feet long, and weighs 680 lb.; and the scape-wheel weighs about half an ounce. This clock is said to be eight times as large as a full-sized cathedral clock; it requires two hours a week to wind it up, and reports its own time to Greenwich by electrical connection; the cost has exceeded £22,000, and the gilding of the clock-tower £1,500.

PRINCIPLES OF DESIGN.—V.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

HAVING considered some of the chief principles involved in the production of decorative design so far as "expression" goes, we come to notice that constant adjunct, or handmaid, of form which has ever played an important part in all decorative schemes—namely, colour.

Form can exist independently of colour, but it never has had any important development without the chromatic adjunct. From a consideration of history, we should be led to conclude that form alone is incapable of yielding such enrichments as satisfy; for no national system of decoration has ever existed in the absence of colour. Mere outline-form may be good, but it is not satisfying; mere light and shade may be pleasing, but it is not all that we require. With form our very nature seems to demand colour; and it is only when we get well-proportioned forms which are graceful, or noble, or vigorous, in combination with colours harmoniously arranged, that we are satisfied.

Possibly this feeling results from our contact with Nature. The flowers appear in a thousand hues, and the hills are of ever-varying tints. What a barren world ours would appear, were the earth, the hills, the trees and the flowers, the sky and the waters, all of one colour! Form we should have, and that in its richest variety; light and shade we should have, with ever-varying intensity and change; but colour would be gone. There would be no green to cheer, no blue to soothe, no red to excite; and, indeed, there would be a deadness, although the world would be full of life, so appalling, that we can scarcely conceive of it, and cannot feel it.

Colour alone seems to have almost greater charms than form alone. How entrancing is a sunset when the sky glows with its radiant hues; the blue is almost lost in red, the yellow is as a sea of transparent gold, and the whole presents a variety and blending of tints, which charm, and soothe, and lull to reverie; and yet all form is indistinct and obscure. If so charming when separate from form, what is colour when properly combined with beautiful shapes? It is difficult, indeed, for many of those for whom I write to answer this question, even by a mental conception; for I could scarcely point to a single building in England which would be in any way a satisfactory illustration of what may be done by the combination of forms and colours. There is a beauty in Art, which we in England do not even know of: it does not exist round us, it is little talked of, rarely thought about, and never seen. A decorator is called in to beautify a house, and yet not one in fifty of the so-called decorators know even the first principle of their art, and would not believe, were they told of the power of the art which they employ. They place on the walls a few sickly tints—so pale, that their want of harmony is not very apparent. The colours of the wall become the colours of the cornice and of the doors, because they know not how to produce a harmony of hues; and the result is a house which may be clean, but which is in every other respect an offence against good taste. I do not wonder that persons here in England do not care to have their houses "decorated," nor do I wonder at their not appreciating the "decorations" when they are done. Colour, lovely colour, of itself would make our rooms charming, but where are the priests who understand their mistress?

There are few objects to which colour may not be applied, and many articles which are now colourless might be coloured with advantage. Our reasons for applying colour to objects are twofold, and here we have the true use of colour. 1st. Colour lends to objects a new charm—a charm which they would not possess, if without it; and, 2nd, Colour assists in the separation of objects, and thus gives assistance to form. These, then, are the two objects of colour. Mark, first, colour is to bestow on objects a charm, such as they could not have in its absence. In the hands of the man of knowledge it will do so—it will make an object lovely or lovable, but the mere application of colour will not do this. Colour may be so applied to objects as to render them infinitely more ugly than they were without it. I have seen many a white bowl so coloured at our potteries as to be much less satisfactory when coloured than when white—the colouring having marred, rather than improved, its general effect. Here, again, it is knowledge that we want. Knowledge will enable us to transmute base materials into works of marvellous beauty, worth their weight in gold. Knowledge, then, is the true philosopher's stone; for if possessed by the artist it does, in truth, enable him to transmute the baser metals into gold. But a little knowledge will not do this. In order that we produce true beauty, we require much knowledge, and this can only be got by constant and diligent labour, as I have before said; but the end to be gained is worth the plodding toil. Believe me, there is a pleasure in seeing your works develop as things of beauty, delighting all who see them—not the illiterate only, but also the educated thinker—such as words fail to express. Although there is no royal road to art power, and although the road is long, and lies through much toil and many difficulties; yet as you go along, there is pleasure in feeling that one obstacle after another is cleared from your path, and at the end there is pleasure inexpressible. The second object of colour is that of assisting in the separation of form. If there is a series of objects placed near to one another, and these objects are all of the same colour, the beholder will have much more difficulty in seeing the boundaries or terminations of each than he would, were they variously coloured; he would have to come nearer to them in order to see the limits of each, were all coloured in the same manner, than he would, were they variously coloured: thus colour assists in the separation of form. This quality which colour has of separating forms is often lost sight of, and much confusion thereby results. If it is worth while to produce and place a decorative form, it is worth while to render it visible; and yet, how much ornament, and even good ornament, is lost to the eye through not being manifested by colour! Colour is the means whereby we manifest form.

Colours, when placed together, can only please and satisfy the educated when combined harmoniously, or according to the laws of harmony. What, then, are the laws which govern the arrangement of colours? and how are they to be applied? We shall endeavour to answer these questions, by making a series of statements in axiomic form, and then we shall enlarge upon these propositions.

GENERAL CONSIDERATIONS.

1. Regarded from an art point of view, there are but three colours—*i.e.*, blue, red, and yellow.

2. Blue, red, and yellow have been termed *primary* colours; they cannot be formed by the admixture of any other colours.

3. All colours, other than blue, red, and yellow, result from the admixture of the primary colours.

4. By the admixture of blue and red, purple is formed; by the admixture of red and yellow, orange is formed; and by the admixture of yellow and blue, green is formed.

5. Colours resulting from the admixture of two primary colours are termed *secondary:* hence purple, orange, and green are secondary colours.

6. By the admixture of two secondary colours a *tertiary* colour is formed: thus, purple and orange produce russet (the red tertiary); orange and green produce citrine (the yellow tertiary); and green and purple, olive (the blue tertiary); russet, citrine, and olive are the three tertiary colours.

CONTRAST.

7. When a light colour is juxtaposed to a dark colour, the light colour appears lighter than it is, and the dark colour darker.

8. When colours are juxtaposed, they become influenced as to their hue. Thus, when red and green are placed side by side, the red appears redder than it actually is, and the green greener; and when blue and black are juxtaposed, the blue manifests

but little alteration, while the black assumes an orange tint or becomes "rusty."

9. No one colour can be viewed by the eye without another being created. Thus, if red is viewed, the eye creates for itself green, and this green is cast upon whatever is near. If it views green, red is in like manner created and cast upon adjacent objects; thus, if red and green are juxtaposed, each creates the other in the eye, and the red created by the green is cast upon the red, and the green created by the red is cast upon the green; and the red and the green become improved by being juxtaposed. The eye also demands the presence of the three primary colours, either in their purity or in combination; and if these are not present, whatever is deficient will be created in the eye, and this induced colour will be cast upon whatever is near. Thus, when we view blue, orange, which is a mixture of red and yellow, is created in the eye, and this colour is cast upon whatever is near: if black is in juxtaposition to the blue, this orange is cast upon it, and gives to it an orange tint, thus causing it to look "rusty."

10. In like manner, if we look upon red, green is formed in the eye, and is cast upon adjacent colours; or, if we look upon yellow, purple is formed.

HARMONY.

11. Harmony results from an agreeable contrast.

12. Colours which perfectly harmonise improve one another to the utmost.

13. In order to perfect harmony, the three colours are necessary, either in their purity or in combination.

14. Red and green combine to yield a harmony. Red is a primary colour, and green, which is a secondary colour, consists of blue and yellow—the other two primary colours. Blue and orange also produce a harmony, and yellow and purple; for in each case the three primary colours are present.

15. It has been found that the primary colours in perfect purity produce exact harmonies in the proportions of 8 parts of blue, 5 of red, and 3 of yellow; that the secondary colours harmonise in the proportions of 13 of purple, 11 of green, and 8 of orange; and that the tertiary colours harmonise in the proportions of olive 24, russet 21, and citrine 19.

16. There are, however, subtleties of harmony which it is difficult to understand.

17. The rarest harmonies frequently lie close on the verge of discord.

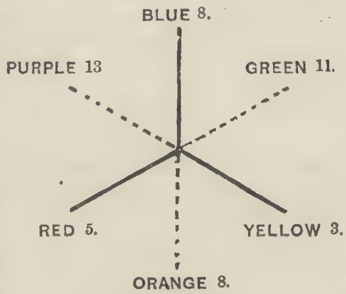


Fig. 17.

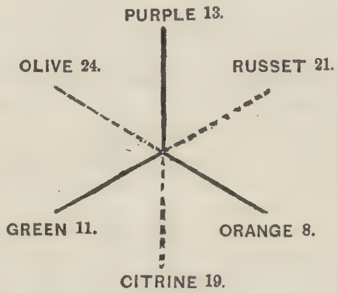


Fig. 18.

18. Harmony of colour is, in many respects, analogous to harmony of musical sounds.

QUALITIES OF COLOURS.

19. Blue is a cold colour, and appears to recede from the eye.

20. Red is a warm colour, and is exciting; it remains stationary as to distance.

21. Yellow is the colour most nearly allied to light; it appears to advance towards the spectator.

22. At twilight blue appears much lighter than it is, red much darker, and yellow slightly darker. By ordinary gaslight blue becomes darker, red brighter, and yellow lighter. By this artificial light a pure yellow appears lighter than white itself, when viewed in contrast with certain other colours.

23. By certain combinations colour may make glad or depress, convey the idea of purity, richness, or poverty, or may affect the mind in any desired manner, as does music.

TEACHINGS OF EXPERIENCE.

24. When a colour is placed on a gold ground, it should be outlined with a darker shade of its own colour.

25. When a gold ornament falls on a coloured ground, it should be outlined with black.

26. When an ornament falls on a ground which is in direct harmony with it, it must be outlined with a lighter tint of its own colour. Thus, when a red ornament falls on a green ground, the ornament must be outlined with a lighter red.

27. When the ornament and the ground are in two tints of the same colour, if the ornament is darker than the ground, it will require outlining with a still darker tint of the same colour; but if lighter than the ground, no outline will be required.

ANALYTICAL TABLES OF COLOUR.

When commencing my studies both in science and art, I found great advantage from reducing all facts to a tabular form so far as possible, and this mode of study I would recommend to others. To me this method appears to have great advantages, for by it we see at a glance what it is otherwise more difficult to understand; if carefully done, it becomes an analysis of our work; and by preparing these tabular arrangements of facts, the subject becomes impressed on the mind, and we see the relation of one fact to another, or of one part of a scheme to another.

The following analytical tables will illustrate many of the facts stated in our propositions. The figures which follow the colours represent the proportions in which they harmonise:—

Primary Colours.		*Secondary Colours.*		*Tertiary Colours.*	
Blue	8	Purple	13	Olive	24
Red	5	Green	11	Russet	21
Yellow	3	Orange	8	Citrine	19

Primary Colours.		*Secondary Colours.*		*Tertiary Colours.*
Red	5	Orange	8	Citrine, or Yellow tertiary 19
Yellow	3			
Blue	8	Green	11	
Yellow	3			
Blue	8	Purple	13	Russet, or Red tertiary . . 21
Red	5			
Red	5	Orange	8	
Yellow	3			
Blue	8	Green	11	Olive, or Blue tertiary . . 24
Yellow	3			
Blue	8	Purple	13	
Red	5			

This latter table shows at a glance how each of the secondary and tertiary colours are formed, and the proportions in which they harmonise. It also shows why the three tertiary colours are called respectively the yellow tertiary, the red tertiary, and the blue tertiary, for into each tertiary two equivalents* of one primary enter, and one equivalent of each of the other primaries. Thus, in citrine we find two equivalents of yellow, and one each of red and blue; hence it is the yellow tertiary. In russet we find two equivalents of red, and one each of blue and of yellow; and in olive two of blue, and one each of red and yellow. Hence they are respectively the red and blue tertiaries.

Figs. 17 and 18 are diagrams of harmony. I have connected in the centre, by three similar lines, the colours which form a harmony; thus, blue, red, and yellow harmonise when placed together. Purple, green, and orange also harmonise (I have connected them by dotted lines in the first of the two diagrams). But when two colours are to produce a harmony, the one will be a primary colour, and the other a secondary formed of the other two primary colours (for the presence of the three primary colours is necessary to a harmony), or the one will be a secondary, and the other a tertiary colour formed of the two remaining secondary colours. Such harmonies I have placed opposite to each other; thus blue, a primary, harmonises with orange, a secondary; yellow with purple; and red with green; and the secondary colour is placed between the two primary colours of which it is formed; thus, orange is formed of red and yellow, between which it stands; green, of blue and yellow; and purple, of blue and red. In the second of the two diagrams we see that purple, green, and orange produce a harmony, so do olive, russet, and citrine. We also see that purple and citrine harmonise, and green and russet, and orange and olive.

* An equivalent of blue is 8, of red 5, of yellow 3.

WEAPONS OF WAR.—IV.

BY AN OFFICER OF THE ROYAL ARTILLERY.

SMALL ARMS (*continued*).

Before quitting the subject of muzzle-loading small arms, of which, together with the descriptions of powder used with them, we have given some account, it may be well to notice the means of ignition usually employed with arms of this class. Nearly the earliest and rudest mode of igniting the charge consisted of a fuse or slow match, which was applied to a small charge of powder placed over the "touch-hole," or vent, as it is now called. A grave inconvenience of this system consisted in the fact that arms could hardly be carried ready primed, at least for any length of time, because the priming was liable to drop out, or if it did not drop out, to become damp. Accordingly, the soldier was compelled to prime his gun just before using it; and as the operation had to be carefully performed, rapidity of fire under this system was out of the question; moreover, the carrying of an ignited match attached to the gun was a source of inconvenience and danger. The match was superseded by the flint-lock, the flint being made to strike a spark as it descended on to the priming charge of powder. In some instances a metallic alloy of iron and antimony was substituted for the flint. The action in both cases was the same; sparks being struck into the priming-charge. Here we come more closely to our present lock and hammer. A spring-lock was necessary to bring the flint violently down, and the hammer by which the flint was held was the direct parent of the hammer by which the percussion cap was afterwards fired. The next important advance consisted in the application of the percussion system to the firing of small arms. It is said that a Scotch gunsmith, called Forsyth, was the first who proposed a percussion fire-arm, for which he took out a patent in 1807; but it was not, we believe, until about 1822 that a percussion musket was introduced—at least in this country—for military use.

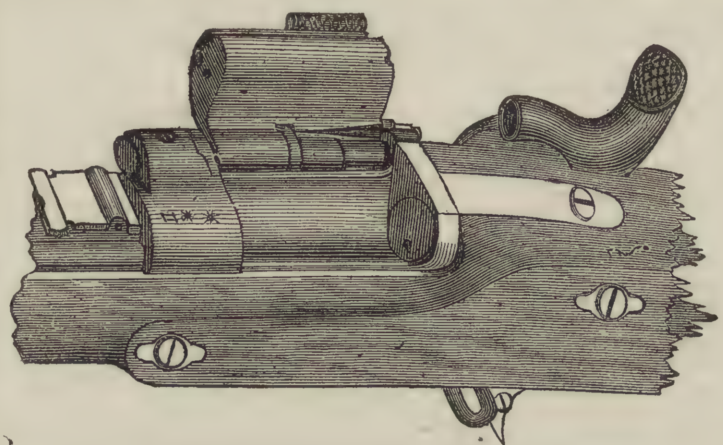


Fig. 1.—SNIDER RIFLE OPEN FOR RECEPTION OF CARTRIDGE.

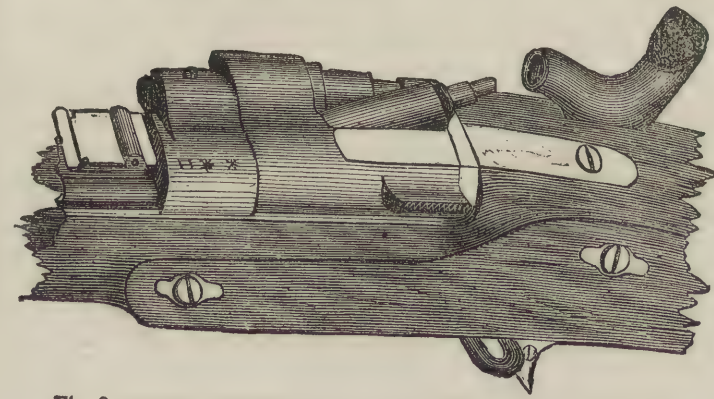


Fig. 2.—SNIDER RIFLE CLOSED AFTER INSERTION OF CARTRIDGE.

It is hardly necessary to insist upon the advantages which the percussion cap presents over the match and flint-lock guns. A moment's consideration will serve to show that the change was a most important one, scarcely less important in its way than the introduction at a later period of breech-loading. To detail the various simplifications and improvements of the lock which have been effected would be tedious; nor is it necessary to set forth the endless varieties of percussion caps and devices for igniting fire-arms by means of detonating composition which have been proposed and attempted since the subject of this improved method of firing was first suggested about sixty years ago. It will be sufficient to say, that the percussion caps for military arms, with the form and appearance of which all our readers are no doubt familiar, are made of pure copper of a superior quality. It is not only necessary to use good copper, because a very small admixture of foreign matter, by affecting its malleability, will interfere with the production of a cap of the required form, but because too hard or brittle a metal would be apt to fly and injure the firer. Partly on this account, and partly because of the liability of zinc to corrosion, the proposition which has been frequently made to substitute that metal for copper has always been held to be inadmissible. For a similar reason our readers should be cautioned against employing, if they can avoid it, the cheap brass caps which are not unfrequently manufactured and coloured to represent copper. In the Government establishments very careful attention is paid to the selection of the copper.

Cap composition varies with different makers, and from time to time it has been altered for military arms. Thus, the composition for the caps for the Enfield rifle consisted of—

	Parts.
Fulminate of Mercury	4
Chlorate of Potash	6
Ground glass	2

—the latter ingredient being added to increase the sensitiveness of the composition, by promoting friction between the particles. When the Westley-Richards and Sharp's breech-loaders were introduced, with which the cap was required to ignite the powder contained in a paper cartridge, a more powerful composition was introduced, namely:—

	Parts.
Fulminate of Mercury	4
Chlorate of Potash	1

This composition proved, however, too violent in its action for use on the nipples of the Enfield rifle, which are of a different form from the nipples of the breech-loading rifles, with which the caps were intended to be used, and a further change was made to a composition consisting of

	Parts.
Fulminate of Mercury	6
Chlorate of Potash	6
Sulphide of Antimony	4

The addition of the antimony secured the flash which was required to pierce the paper envelope of the cartridge, while at the same time it modified the intense violence of action of the cap, and prevented it from "flying" into pieces, and causing inconvenience and injury to the firer.

One more point with regard to percussion caps, and we pass on to another subject. This point is the waterproofing of the cap. Several methods have been tried, and are in vogue for rendering percussion caps waterproof; or, which is of more importance, for enabling them to resist damp. Among these may be mentioned the covering of the composition with a thin metallic disc, or with a disc of india-rubber. The simplest and probably the most effective plan is that which is applied to the Government caps, viz., to subject the composition to considerable pressure, by which means it is reduced to a stony hardness, and is rendered almost impervious to moisture; while by coating the composition with a strong varnish of shellac the caps are ultimately made completely waterproof.

We have now dealt generally with all the points which con-

nect themselves with muzzle-loading rifled small arms. We have considered the bullet, the charge, the means of ignition, the rifling, the weight and character of the arms. These elements, judiciously combined, gave us in the Enfield rifle a military weapon of great excellence. But there were two important directions in which improvements seemed necessary and possible. The first and most important consisted in increasing the rapidity of fire; the second in increasing the ballistic power of our weapons, an expression which covers all the shooting qualities of an arm—its accuracy, range, flatness of trajectory, penetrative powers, etc.—as distinguished from those qualities which connect themselves with easy and rapid loading, etc.

In short, the advantages of the Enfield rifle as an arm of precision were no sooner recognised than men began instinctively to endeavour to simplify and accelerate the operation of loading by introducing the cartridge at the breech. In the case of the cavalry soldier this was a matter of no small importance. The difficulties of loading a rifled arm on horseback were considerable; and thus we find that as early as 1857 steps had been taken towards the supply of breech-loaders to mounted men. In that year some Sharp's breech-loading carbines were issued to two regiments of cavalry. The charge in this arm was inserted bodily at the breech; and as the block ascended it cut off the end of the cartridge, and exposed the powder, which was fired in the same way as a muzzle-loader, with the ordinary percussion cap. The Sharp breech-loader, which is still used to some extent by our cavalry in India, is an extremely bad breech-loader, for several reasons—among them the great escape of gas which occurs at the breech on firing, and the employment of a percussion cap.

The Westley-Richards carbine was a great improvement on the Sharp, for the end of the cartridge was not cut off in loading, and the escape of gas was prevented by means of a felt wad attached to the back of the cartridge. In this wad we see a sort of rude prototype of the present non-consuming cartridge—an imperfect application of the present system of making the cartridge do the work of checking the escape of gas. We recognise here, also, in this half solution of the question, a dim perception of the fact now so fully admitted, that the cartridge is the turning-point or hinge upon which the success of a breech-loading small-arm depends. Here, for example, we have, in the Westley-Richards, a superior combination to that which existed in the Sharp; and why? Not because of the superiority of the breech-action of the Westley-Richards, for it may be doubted if the Sharp action (upon which the present admirable Henry breech-loader is based) is not in fact the better of the two. No; but simply because Westley-Richards was on the right track with regard to his cartridge, and Sharp was on the wrong track. It should here be mentioned that, as an arm of precision, the Westley-Richards carbine was a very good one. It was a "small-bore" rifle—an expression to which we will assign a definite meaning hereafter—and it threw a 400-grain bullet, with a 2-dram charge, with great accuracy to a long range. But the rifle (which is now, we believe, in the hands of the yeomanry cavalry) is open to several objections—among them, that it is fired in the old way by means of a percussion cap. So long as this mode of ignition is retained, it is impossible to realise the full advantages of a breech-loader. It is fair, however, to observe that it was through no fault of the inventors that this objectionable feature in the Sharp, Westley-Richards, and other breech-loading rifles was retained. The fact is that the authorities set their faces determinedly against cartridges containing—like those now in use for the Snider—their own means of ignition. It was supposed that such cartridges were liable to accidental explosion *en masse* by the ignition of a single cartridge in the barrel or box, and the consequences of such an accident were likely to be so serious that any cartridge of this description was considered inadmissible. We thus perceive that a serious barrier existed at this time to the development of the breech-loading question. It was regarded as essential to employ the old muzzle-loading means of ignition, and greatly accelerated rapidity of fire—one of the principal, though not the only, advantage of breech-loading—was impossible with a capping breech-loader; so that for several years the question was considered mainly as a cavalry question, facility, but not rapidity, of loading being the thing aimed at. Indeed, rapidity of loading was rather deprecated than otherwise. Many good soldiers and experienced officers declared that if you gave a soldier a gun which he could load very quickly he would expend all his ammunition before he came within effective fighting range. It may be admitted that breech-loaders are open to this objection, although not to anything like the extent commonly supposed, and the objection is one which can be remedied by discipline and an effective, careful training. The practice of the Prussians is an example of this. Here we have a nation which really understands the breech-loader, which is properly trained in its use and in the economical expenditure of ammunition, and the results we have seen in two great wars. On the other hand, we have the excitable, and, we may be permitted to add, badly-trained, ill-drilled, ill-disciplined French soldier, blazing away at any number of mètres from the enemy, and running out of cartridges early in the day. Cannot the English soldier do what the Prussian does? Is our national temperament so excitable, so unlike that of the Prussians, that no training can teach our men that the fighting unit is a man *plus* a cartridge, not a man by himself with an empty pouch? Then, again, it is to be observed that although a somewhat wasteful expenditure of ammunition may be one of the results of the introduction of breech-loaders, the non-issue of breech-loaders would be tantamount to the destruction of the army. If a soldier is likely to fire too rapidly in the one case, he is certain to be unable to fire rapidly enough in the other. The one defect may be corrected or controlled; the other, so long as muzzle-loaders are in use, cannot be. It is not a question of expediency, it is a question of sheer necessity. Whether or not breech-loading rifles may be attended with certain disadvantages is a point which admits of discussion, but it admits of no discussion that breech-loading rifles are vital to the very existence of an army. If the disadvantages are there they must be made the best of; and the way to make the best of this special disadvantage is so to train the soldier, so to drill and discipline, so to hammer at him, that he will come to understand that a shot ought never to be thrown away. And if he only act upon this principle, it will be no objection that he is able to fire a dozen shots a minute instead of three, and thus to do his work in one-fourth the time.

What we have written may appear to have an historical rather than a practical interest. A little consideration will, however, serve to show that this is not the case. It is in the history of the subject that its foundations repose. In the recognition of the difficulties which beset the earlier attempts, and the objections which stunted the growth of the question; in the perception of the growing importance of the cartridge question, and the relatively inferior importance of the breech mechanism; in the recognition of the fact that the question of breech-loading is quite distinct from and independent of the question of shooting—of ballistic power—we have the elements of the subject. Let us pass now to their practical application.

Up to about 1864 the question of breech-loading was treated, for reasons which we have endeavoured to trace in outline, as one which principally affected the cavalry soldier. But in 1864, instructed by the experience of the Dano-German war, General Russell's committee recommended that the British infantry be armed with breech-loaders. The question then arose, What breech-loader should be provided? I need not now trace all the discussion which took place at the time, or set forth the arguments which ultimately prevailed to secure the adoption of the Snider system of conversion. The Enfield rifle was thought, and properly thought, to be so excellent a shooting weapon, that it was considered that it would be sufficient, at least for the present, if this rifle were provided with an arrangement which, without affecting its shooting, would permit of its being fired more rapidly. In this way, while the British army could be rapidly re-armed with an effective breech-loader, ample time would be given for working out the question which would still remain of a totally new breech-loader for future manufacture. About fifty systems of conversion were submitted to Government, in reply to an advertisement dated August, 1864. Of the five systems which were preferred by the committee only one was a non-capping breech-loader, and that was the Snider. Ultimately, after some extensive trials, the Snider was adopted. Most of our readers are probably more or less familiar with the breech-action of the Snider rifle—the block hinged upon the side of the "shoe," and containing the piston or striker, by means of which the blow is communicated from the hammer to the cap.

Those who are unacquainted with this arm will be able to understand its construction from the illustrations in page 193.

The whole of the serviceable long and short Enfield rifles are rapidly being converted into breech-loaders on this system; and these, with the addition of some thousands of *new* Snider-Enfields, will give us about 700,000 Sniders by the end of March, 1871. The regular army, and we believe the militia, are already armed with this weapon; the armament of the volunteers is now proceeding. The Snider rifle was subjected to a good deal of hostile criticism on its first introduction, which has been sufficiently answered by the experience of the past three or four years. We now hear little censure of the arm. It is obviously open to the objection that the calibre is too large, and that it is inferior as an arm of precision, and even as a breech-loader, to some of the more modern examples of military breech-loading arms; but the simplicity, efficiency, and durability of the breech mechanism are now universally admitted; and as for its shooting qualities, the weapon is at least as efficient as the Enfield rifle. With regard to the durability of these arms, it may be mentioned that the writer of these papers has seen several Snider rifles which have fired 40,000 and 50,000 rounds: he has seen one which has fired over 70,000 rounds, and which is still serviceable.

We have yet to speak of a very important element in the new arm—the cartridge. It is not too much to say that it is rather to the cartridge than to the breech mechanism that the arm owes its success. The breech mechanism, it should also be understood, was not an easy one to construct a cartridge for, because (1), in the event of a failure on the part of the cartridge, the block was liable to be blown open; (2) the difficulty—we might say, the impossibility—of making the block fit accurately and closely against the base of the cartridge rendered the strain upon the cartridge case peculiarly severe; (3) the extraction of the empty case had to be performed by hand, and without any leverage or mechanical assistance, and therefore must be easier than is necessary for guns in which "power" can be applied. But there were other conditions besides those of strength and easy extraction which the cartridge was required to fulfil. What they were, and how they have been satisfied, will be explained in another paper.

BUILDING CONSTRUCTION.—VII.

BRICKWORK (*continued*).

Brickwork should not be carried on in frosty weather, and even if such is expected, it is advisable, where possible, to delay the building. Unfinished walls should be covered with straw, on which boards, called *weather-boards*, should be laid. By attention to this simple matter injury to walls might often be prevented.

The introduction of substances other than those composing the walls should be as far as possible avoided. In general, however, some wooden members are required, but these should be treated with the greatest caution, so that they may not be crushed by the weight above them, or lest the superstructure, by being made to rest upon them, might become liable to sink should the wood decay. The principal wooden parts of the structure which are connected with the brickwork are the wall-plates, templates, lintels, and wood-bricks.

Wall-plates are pieces of timber laid lengthwise on the top of a wall to receive the ends of the floor-joists, which rest upon them. This will be fully treated of under the head of Flooring, and is only referred to in this place to explain the purpose of wall-plates in relation to the walls. It will be clear that if the joists were tailed singly on the walls themselves the pressure of each individual timber would be on a single brick and those which support it, whilst those between the joists would not in any way share the burden. The wall-plate then, resting as it does on the wall, distributes the weight over the whole length; and thus all parts of it bear alike. The application of a wall-plate will be shown in an illustration in a future lesson.

The purpose of *templates* (called also *templets*) is similar to that of wall-plates. They are used in a stronger form of flooring, which will subsequently be treated of, called "framed floors," the weight of which is borne by a few very large girders. Under these are placed the templates, which are stout pieces of timber two or three feet long; these, like the wall-plates, serve to spread the pressure over a wider surface than that on which the girders would otherwise rest.

Fig. 43 shows the section of a girder resting on a template. Now it is necessary, first, that pressure should be averted as much as possible from the end of this girder; for, in the event of damp striking it, or its rotting, it would give way under the weight. Secondly, the upper portion of the wall should receive no support from the girder by resting on it; for, should the

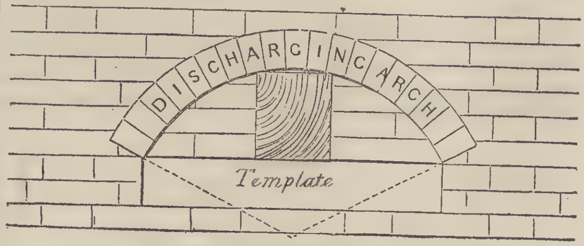


Fig. 43.

girder warp, sag, or by any means shake, the brickwork dependent upon it would crack and give way. The arch, then, turned over the end of the girder and lintel, not only supports the wall above, but "discharges" the weight over the walls on each side.

Lintels are pieces of timber placed over the square-heads of windows; they are used to preserve the square form, and for the attachment of the wooden lining of the under surface of the opening called the *soffit*, etc. They should not, however, be allowed to bear the weight of the wall above, under which they would certainly give way; and any sagging in the middle would cause their ends to rise, by which the entire brickwork would be disturbed. It is therefore necessary to build "discharging" arches over them. The principle on which arches are constructed will be considered further on; it is therefore only necessary here to demonstrate their use in relieving the lintel from pressure.

Fig. 44 illustrates the position of a lintel, over which a discharging arch is placed, for the same purpose as that above. This cut also shows the application of *wood-bricks*, w, w. These are used for the attachment of joiner's work in the jambs

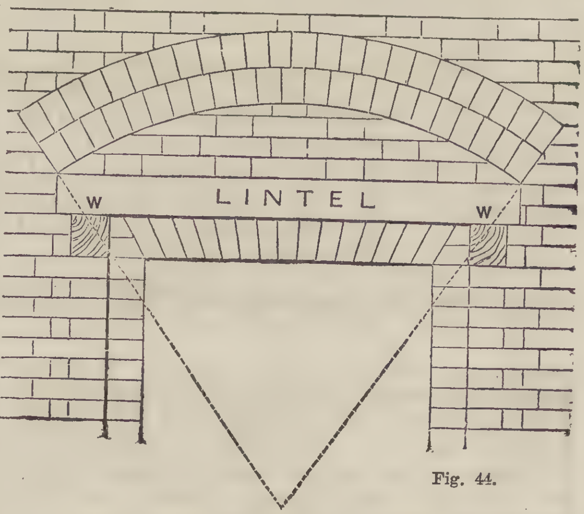


Fig. 44.

of the windows and doors, for their fittings, and along the walls at certain heights for the skirtings or wainscoting to be nailed to. It is scarcely necessary to remind workmen that it is worse than useless to drive nails into mortar between bricks; and that therefore when it is necessary to drive a nail into a wall already built, the wall must be *plugged*, that is, wedges of wood must be driven in, and into these the nails may be hammered. But the use of wood-bricks supersedes the necessity of wedges in a wall in course of building, and as it is known beforehand what fittings are to be attached, the blocks of wood

cut to the exact shape and size of the bricks can be worked in as bricks at the points in the wall where they will be required by the joiner.

Wood-bricks are, however, gradually going out of use. It is found better to insert a piece of timber of the thickness of the joint of the brickwork—viz., about ¼ or ⅜ thick, which shrinks less than a wood-brick, and still affords sufficient hold for the nails.

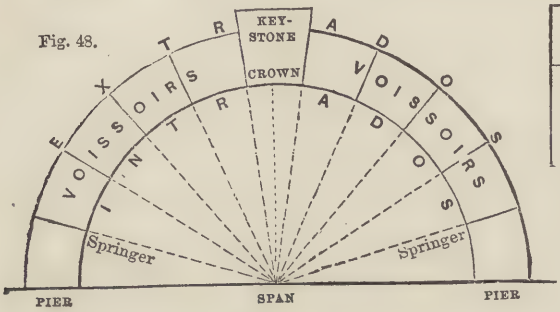
Bond-timbers are long pieces of wood like continuous wood-bricks. They are not much used now. Their purpose is to bond the bricks together, and for the attachment of mouldings, wainscoting, etc.; but they are liable to shrink, swell, and decay, according to the situation in which they may be placed; and further, in the event of taking fire, they burn away, and

if designed by another. Let us then state once for all, that every curved covering to an aperture is not necessarily an arch. Thus, the stone which rests on the piers shown in Fig. 45 is not an arch, being merely a stone hewn out in an arch-like shape; but at its top, the very point (A) at which strength is required, it is the weakest, and would fracture the moment any great weight were placed upon it.

Equally faulty is the annexed example of an early Egyptian attempt (Fig. 46), in which the first course of horizontal stones projects beyond the piers, and on these rest a third, hewn out to complete the form; and here again we have weakness where strength is required.

At Etruria, and also at Phigalia, constructions similar to Fig. 47 have been found, which are, if possible, worse in principle

Fig. 48.



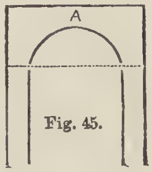


Fig. 45.

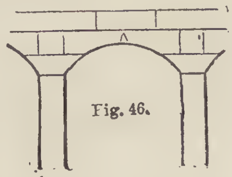
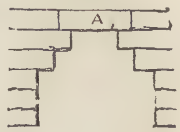


Fig. 46.

Fig. 47.



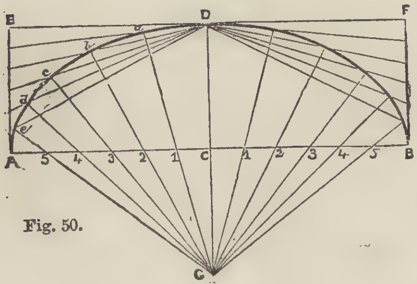


Fig. 50.

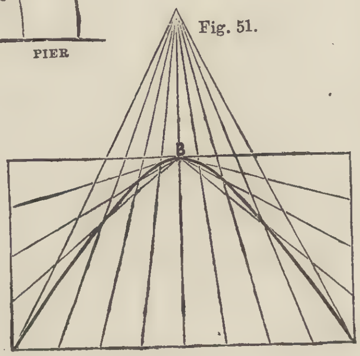


Fig. 51.

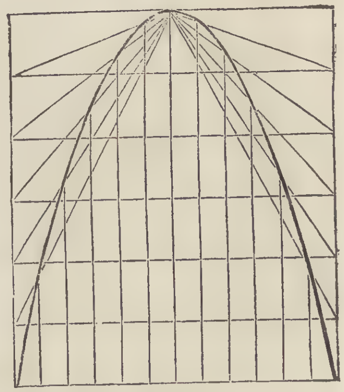


Fig. 52.

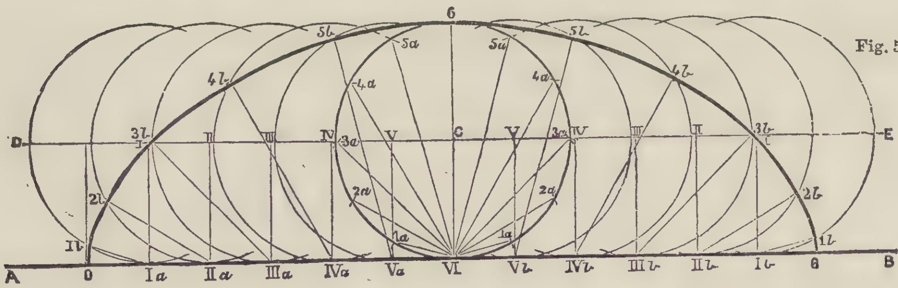
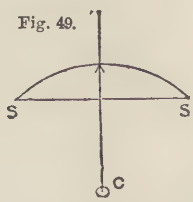


Fig. 53.

Fig. 49.



thus the wall resting on them is weakened. Their use in England is now almost entirely superseded by hoop-iron. Thin and narrow strips of this metal, tarred, are laid in the bed-joints of the mortar, at intervals more or less frequent, according to the thickness of the wall; and they are found in every way effective, whilst it has been shown that the joiner's fittings may be attached to single wood-bricks, on which so much structural strength or safety does not depend.

ARCHES.

Arches have been incidentally spoken of, but they form such an important feature in building construction, that it is deemed advisable that they should be treated of separately. It is necessary, then, that the student should have a very clear conception as to what an arch really is. For if a positive conclusion has not been arrived at, and if the "arch principle" is not thoroughly understood, he cannot be expected to design an arch, or to construct it with accuracy or intelligence, even

than the previous ones; for it is clear that, unless the upper slab be longer than the width of the opening, and the lower stones are weighted at their tail ends, the whole must fall in the moment any weight rests on A.

We come, then, to the point at which it is required that we should state, as briefly as possible, what an arch really is.

An arch, then, is an assemblage of stones or bricks, so arranged that they may by mutual pressure support not only each other, but any weight that may be placed upon them.

The leading principles in the construction of an arch are—

1. That all the stones of which it is formed shall be of the form of wedges; that is, narrower at the inner than the outer end.

2. That all the joints formed by the meeting of the slanting sides of the wedges should be radii of the circle, circles, or ellipse, forming the inner curve of the arch, and will therefore converge to the centre or centres from which these are struck.

These two brief statements will serve at the present stage to

make clear to the mind of the student the general principles of an arch; the mathematical reasonings connected with the designing of arches to bear certain weights are omitted, as not coming within the scope of this course of lessons, but the writer is very anxious that the student should clearly comprehend and not misconstrue the cause of this omission. It is *not because he deems this mathematical knowledge unnecessary*, but simply because he wishes to give information to students who have not had opportunities of acquiring such. Elementary works on the various mathematical subjects connected herewith can, however, be easily obtained; and all who would really study principles, and appreciate the exquisite refinement of the examples herein given, are strongly urged to read them.

Referring to Fig. 48, we will first explain terms. The under surface is called the *intrados*, and the outer the *extrados*. The supports are called the *piers* or *abutments*, though the latter term is one of more extensive application, referring more generally to the supports which bridges obtain from the shore on each side than to other arches. The term *piers* is, as a rule, supposed to imply supports which receive *vertical* pressure, whilst "abutments" are such as resist *outward* thrust. The upper parts of the supports on which an arch rests are called the *imposts*. The *span* of an arch is the complete width between the points where the intrados meets the imposts on either side; and a line connecting these points is called the *springing* or *spanning line*.

The separate wedge-like stones composing an arch are called *voussoirs*, the central or uppermost one of which is called the *key-stone*; whilst those next to the imposts are termed *springers*.

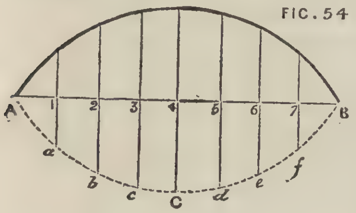


FIG. 54

The highest point in the intrados is called the *vertex* or *crown*, and the height of this point above the springing line is termed the *rise* of the arch. It will be evident that in a semicircular arch, such as Fig. 48, this would be the radius with which the semicircle is struck. The spaces between the vertex and the springing line are called the *flanks* or *haunches*.

The following are the varieties of arches used :—

The *Semicircular*, as shown in Fig. 48; the *Segment* (Fig. 49), in which a portion only of the circle is used—the centre C is therefore *not* in the springing line S, S; the *Elliptical* (Fig. 50); the *Hyperbolical* (Fig. 51); the *Parabolical* (Fig. 52); the *Cycloidal* (Fig. 53).

The methods of constructing these various curves are fully elucidated and illustrated in the lessons in "Practical Geometry applied to Linear Drawing," and it is therefore not necessary to repeat them in this place.

The *Catenarian* (Fig. 54), the form of which is the reverse of the curve taken by a chain or heavy rope when suspended between two points, as A B. A simple mechanical method of describing this curve is as follows:—Draw the springing or spanning line, A B, and bisect it by a perpendicular; place your drawing-board upright, and having marked on the central perpendicular the length 4 C, equal to the height of the required arch (the *rise*), fasten a cord at A; place a nail at B, and, suspending the cord over it, draw it until it gradually reaches C; then fasten it, and with your pencil carefully trace the curve thus formed, being guided by, but not disturbing the cord, which should be first *wetted* and drawn between the fingers. A further improvement on this method is to obtain a quantity of shot, drilled through their centres like beads, and thread them on a fine flexible cord, such as silk, having previously slightly rubbed them over with common black lead. When this loaded cord has been accurately placed, press gently on the shot, and thus a series of marks will be made on the paper. The curve drawn through these points will be the *Catenary*.

Now set off any number of divisions on each side of the centre, and draw perpendiculars through them, cutting the curve in *a*, *b*, *c*, C, *d*, *e*, *f*, and passing through the span A B in 1, 2, 3, 4, 5, 6, 7; set off all the perpendiculars *above* the spanning line, the lengths of 1 *a*, 2 *b*, 3 *c*, etc.; join these points, and the curve will be the catenary inverted, as used in the catenarian arch.

CHEMISTRY APPLIED TO THE ARTS.—IV.

BY GEORGE GLADSTONE, F.C.S.

CALICO PRINTING.

CALICO printing forms now one of the greatest industries of the country, and is destined steadily to increase as the great foreign markets become more and more opened up to British commerce. It is associated with the names of many of the wealthiest families of Lancashire and Glasgow, such as the Peels, whose enterprise in availing themselves without delay of every improvement in the art, led to the realisation of that fortune which enabled the late statesman to devote himself to a public career.

From the earliest ages down to the end of last century, what is termed "hand-block printing" was universally practised, and it still continues to be to some extent. Block printing by machinery has since been introduced; but though the machines employed for this purpose are very ingenious and beautiful, they would never have sufficed to meet the rapidly increasing demands of the trade. It is to the invention of the cylinder machine that the prosperity of our manufacturing districts is so largely indebted.

Block printing, as distinguished from cylinder printing, consists in stamping the calico with a pattern raised in relief upon the block, after being moistened with the composition which is intended to be transferred to the cloth. The hand-block varies somewhat in size, according to the pattern or work required; but it is commonly about nine inches long and six broad, with a handle for the sake of convenience. The pattern is sometimes cut out in relief upon the wood, but this is liable to wear down very rapidly, so that it has been found greatly preferable to raise the pattern on the block, by inserting strips of copper of the desired form and thickness into the wood, by which means a sharper and more durable design can be obtained. The mordant, or dye stuff, as the case may be, is applied to the block by pressing the latter upon what is termed a "sieve" (a box covered with woollen cloth), which is kept moist by the composition below working its way up through the interstices, and then the cloth is stamped with it at the regular distances required to produce the pattern. Another mode of charging the block with the dye is to pass a moistened roller over it, after the manner generally adopted for applying ink to letterpress. Several colours may, however, be printed simultaneously with one block; in which case the sieve must be divided into as many compartments as may be required, each division corresponding in shape and size with the portion of calico which is to receive a certain mordant or dye. If the several colours are to form parallel lines, whether straight or waved, the roller can also be readily adapted to this purpose. A piece of print would ordinarily require about 450 separate applications of the hand-block, involving a very serious expense for labour, as well as occupying a considerable time; especially as each impression must be adjusted with the utmost nicety, or there will appear to be breaks or irregularities in the pattern. In order to increase dispatch, and at the same time to secure great precision in the joining of the pattern, machinery has been adopted; the most complete invention of the kind being the "Perrotine," so named because it was brought to perfection by M. Perrot, of Rouen, one of the chief centres of the French cotton manufacture.

Cylinder printing has now almost superseded all the other processes, those previously employed having no chance of competing with it, either as to precision or dispatch. It dates from about the year 1785. It differs in several particulars from the block system. In the first place, the pattern is not raised upon the cylinder, as in the block, but cut into it, by which means fine lines can be produced without suffering much from wear and tear; in the second, it can be arranged with such precision that the pattern shall be continuous; and in the third, the printing can go on without intermission, so that there is an immense saving of time. The multiplication of different colours in one pattern can also be much more easily effected by the adoption of this system, as almost any number of cylinders can be adapted to the machine, according to the number of colours desired.

The following description of the actual operations will be confined to cylinder machine printing, as the block system only varies from it in the mechanical arrangement. The several

processes which a piece of goods ordinarily passes through at a printing establishment consist of printing, stoveing (in which ageing is included), dunging, dyeing, brightening, and dressing. There are, however, some special processes adopted to produce different styles, which will be described afterwards. They may be regarded as additions to, or variations from, the ordinary style.

Printing.—It will be seen at once that the result depends upon the same chemical reactions as have been fully explained in the previous articles upon Dyeing; and it will be necessary to bear in mind the special functions of mordants and alterants. The colours which the piece of goods is hereafter to assume are not printed upon it, but only the mordants, which are to take them up afterwards, and to fix them. The pattern being engraved upon the copper cylinder, it has to be charged with the mordant, which must be of such a consistency that it will neither run too freely, nor stick to the metal. With this object, it is usually thickened with flour, starch, pipeclay, sugar, glue, gum, etc., but the quantity of such ingredients varies a good deal, according to the character of the design; and the thickenings themselves must be selected with reference to the substances contained in the mordants, some of the salts used for this purpose causing starch or flour to coagulate, while others have the same effect upon gums—which renders them quite unfit for the purpose. The mordants have, of course, to be likewise selected with reference to the colours which it is intended to produce, so that, on subsequently steeping the cloth in the dye, different chemical reactions may take place, and thus bring out the variety of colours or shades required. Thus mordants made with iron salts and alums in various proportions will serve to produce all kinds of tints from red to purple, and even to brown: by omitting the alum altogether, a black may be produced; and, on the other hand, an aluminous compound without any iron salts will serve as a mordant for orange. Each cylinder employed, being arranged so as to fit into its exact place in the pattern, and charged with its respective mordant, passes over the cloth in succession, discharging the mordant upon it, which then passes at once into another chamber, in order to undergo the next process. The printing, however, cannot be satisfactorily performed unless the cloth be damp, a certain amount of moisture being absolutely necessary in order to ensure the mordant's thoroughly adhering to the fabric; but if, on the contrary, it should be made too wet, the mordant would be liable to run, and the sharpness of the pattern would be marred. In order that the proper medium should be secured, and that the whole piece should be of uniform dampness, it is found best to let the goods lie in a damp atmosphere for some time, and that the printing-room should be maintained at a pretty high temperature with the air thoroughly saturated with moisture.

Stoveing.—Immediately after coming off the printing-machine, the cloth is passed through a hot flue, in order to dry the substance taken off the cylinders before it has time to spread, which action would be encouraged by the dampness of the fabric. In the act of drying, the mordants adhere more closely to the fabric, especially if acetates of iron have been used, the acetic acid being driven off by the heat, and leaving the iron free to unite with the cloth. The hot flue leads into the ageing-room, where the cloth remains suspended for about a couple of days, to complete the fixing of the mordants, so far as exposure to the influence of the atmosphere will carry the process.

Dunging.—This is a very necessary operation, and is so named from cow-dung being usually the material employed for the purpose. Other ingredients are sometimes used as substitutes, and there are cases also when a bran-bath will suffice. The valuable properties of the dung appear to consist in the phosphorus compounds and the albuminous matters contained in it; and the natural combination is preferable to the chemical preparations which are in some instances used instead. The result produced is a double one; it fixes more thoroughly the iron salts and aluminous mordants which have been transferred to the cloth in the act of printing, while at the same time it carries off the ingredients which have been introduced as thickenings, so as to expose the mordants to the full action of the dye which is presently to be applied. It is usual to pass the goods rapidly through two separate baths made of a solution of this material in warm water, the tanks being arranged with a series of rollers on each side, over which the fabric is drawn alternately, so that a very large surface is exposed to the action of the bath. Between each of these immersions the goods should be well scoured in the dash-wheel (similar to what is used in bleaching), so as to carry off the extraneous matters.

Dyeing.—Up to this stage, although the pattern has been printed upon the cotton, the effect is not manifest, the slight colour which may have been conveyed to the cloth with the mordant having no reference to that which is intended to be ultimately produced. This comes out during the dyeing; the mordanted portions of the cloth—which exactly correspond with the pattern, or combination of patterns, engraved upon the cylinders—taking up the dye, and producing, with the various mordants employed, the variety of colours required to produce the desired result. The chemical processes upon which this depends will be readily understood by those who have read the previous articles on Dyeing, but the practical details will need some further description. One of the dyes most commonly used for this purpose is madder. A solution of it is made in the dyebeck—a long vessel containing the dye in solution, above which a roller or reel extends for its whole length, over which the cloth passes; and, being made to revolve by a winch, it carries the fabric with it, so that the whole surface becomes equally exposed to the action of the dye, and by repeated revolutions has as large a surface as possible brought under its influence within a given time. The immersion in the dyebeck should occupy four or five hours, during which period the temperature should be gradually raised from a tepid to the boiling heat. The addition of a little chalk, especially if the water should be very pure, greatly heightens the effect of the madder. Should it be intended that the mordant printed from any one cylinder shall take up no other dye than madder, the process above described must be repeated until the mordant is thoroughly saturated, so that it may be rendered incapable of taking up any of the dyes to be subsequently applied for other parts of the pattern. Suppose, however, an orange be desired, the maddering would be stopped sooner, in order that some of the mordant might remain free to combine with the yellow dye. The same plan is adopted when solutions of quercitron, sumach, and other dye stuffs are used.

Brightening.—The next step (sometimes called "clearing") is for the purpose of bringing up the colours to their full brilliance, and at the same time of finishing the operation of fixing. This is attained by passing the goods through a soap bath two or more times, according to the dyes which have been previously applied, the second immersion being usually in a slightly acid solution. Between each bath the fabric should be thoroughly rinsed and exposed to the air. The effect of these operations is to clear the unmordanted portions of any colour that may be adhering to them, so as to obtain a perfectly white ground, and also to discharge from the rest of the surface any excess either of mordant or dye which has not entered into combination with the other. Some dyes, however, will not bear the action of soap, and for clearing these a bath of bran is used instead, the goods being immersed for about half an hour, during which time the liquor is raised to the boiling-point. After this they only require dressing, in order to give them a proper finish for the market.

Such is a brief description of the process in most general use for printing calicoes. The ingredients principally employed as mordants are alumina and the salts of tin and iron, different combinations of which are worked up with gum and other thickenings, in order to make the various pastes for feeding the cylinders upon which the several parts of the required pattern are engraved. The dye-stuffs which are subsequently used for producing a permanent colour with the various mordants have already been named in the articles on Bleaching, the calico printer having to consider the varied affinities of certain dyes for the several mordants which have been used in printing the pattern, so that they shall produce such colours, or combinations of colour, as shall make a harmonious whole. Madder, cochineal, and safflower are much used for various shades of red; chromium, yellow berries, and quercitron, for yellows and orange; the double cyanides of potassium for blue; while combinations of these, by successive applications in the dyebeck upon appropriate mordants, will produce the intermediate colours. The selection of the most suitable dye-stuffs, so as to realise the best effect, is a matter of considerable importance;

nor is the order in which the dyes are applied a matter of indifference, the general rule, however, being that the darkest colours should be dealt with first.

There are yet other processes connected with calico printing to be described, which must form the subject of another article.

TECHNICAL DRAWING.—XIII.

DOVETAILING.

We do not know any branch of carpentry or joinery which so much shows whether the workman is a "good hand" or not, as the way in which he joins timber at the angles. We say "carpentry and joinery," because carpenters are constantly called upon to build wooden cases for cisterns and similar constructions; and, therefore, this lesson refers to them as well as to joiners. Certainly it applies to all *young* workmen, for they, above all, must learn accuracy in joining, and must acquire the power of cutting wood, so that every part may fit without being hacked, chopped, chiselled, or shaved, by which material, time, and patience are wasted, and, in consequence, bad work ensues. It is, of course, desirable that a joiner should work *quickly;* but it is by far more important that he should work *well;* that he should join his materials with firmness and accuracy; that he should make the surfaces perfectly even and smooth, the mouldings true and regular, and the parts intended to move so that they may be used with ease and freedom.

It is also of the greatest importance that the work when thus put together should be constructed of such dry and sound materials, and on such principles, that the whole should bear the various changes of temperature and of moisture and dryness, so that the least possible shrinkage or swelling should take place, and that frames, panels, or doors should not warp or twist. We have seen the great effects of encouraging good workmanship in iron and in the construction of machinery, which is now one of the industries for which this country is famed throughout the world: let us attach the same importance to our wood-work, and there is no reason why we should not in that branch attain a similar position.

One of the most important methods employed by the joiner is that termed *dovetailing*, which is of three kinds—namely, common, lap, and mitre. *Common dovetailing* shows the form of the pins or projecting parts, as well as the excavations made to receive them. Fig. 108 shows the ends of the two boards, *a* and *b*, to be thus joined, and Fig. 109 shows the joint completed. Fig. 110 represents a variation of this form, used in attaching the fronts of drawers to the sides, and for similar purposes. Here the dovetail is shown on the one side only, a ledge being left at the end of *a* so that the ends of the dovetails of the side *b* do not penetrate quite to the front.

Lap dovetailing is similar to this; but in that system the ends of the dovetails of the side *a* are shortened, and the recesses which are to receive them in *b* are not cut through; when joined together, therefore, only the ledge is visible on the return side.

Mitre dovetailing—sometimes called also *secret dovetailing*—conceals the dovetails, and shows only the mitre at the edges. The manner in which this joint is effected will be understood from Fig. 111, in which the two parts A and B are given, each part being lettered to correspond with the position it is to occupy when the sides are joined. Concealed dovetailing is particularly useful where the faces of the boards are intended to form a salient angle, that is, one which is on the *outside* of any piece of work; but where the faces form a re-entrant angle—that is, a joint to be seen from the *inside*—common dovetailing will answer best; for, first, it is stronger, because the dovetails pass entirely instead of only partly through; secondly, it is cheaper, for the dovetails which go through the whole wood take up so much less time in working than where a mitre has to be left; and further, if well executed, the dovetails are, by the very nature of the work, concealed internally.

Fig. 112 exhibits a method of joining two boards at right angles to each other. This is the simple mortise and tenon, and will not require any explanation.

MOULDINGS.

Mouldings are classed as Roman, Grecian, and Gothic.

The Roman mouldings are all formed of parts of circles, and can therefore be struck with compasses. The Grecian are principally composed of parts of curves known as the *conic sections*—such as the ellipse or hyperbola. They are otherwise nearly similar to the Roman, which are therefore illustrated in this place as being the simpler and the more generally used. The modes of describing the conic sections will be found in the lessons in "Practical Geometry applied to Linear Drawing."

Fig. 113.—The moulding of which this is a section is called the *Ovolo*, or quarter round. The fillet, or straight edge projecting beyond the curved portion, is to be drawn first, and then the horizontal, which represents the depth or bottom line of the moulding. Now produce the bottom line of the fillet, and on it, from the point at which the curve is to start, mark off the width of the moulding. The point marked ⊙ in the cut, is the centre from which the quadrant is to be struck.

Fig. 114 is called the *Torus*, or half-round. Having drawn the fillet, and the line representing the bottom of the moulding, draw a line at right angles to these. Bisect the width of the curved part, and the bisecting point will be the centre.

Fig. 115 is the *Cavetto*, or hollow. This is a quarter-round, the curve turning *inward*. It is thus precisely the reverse of the ovolo.

Fig. 116 is a section of the moulding called the *Cyma Recta*. The exact form of this moulding is to a certain extent a matter of taste, since the curve may be made more or less full, as shown in the three examples, Figs. 116, 117, and 118. To describe Fig. 116, draw a perpendicular across the depth of the moulding, and bisect it. From the bisecting point as a centre point describe a quadrant; through the centre draw a horizontal line, and from the point where the quadrant already drawn touches this line mark off the radius; then from this point as a centre describe the second quadrant, which will complete the form. In this and the subsequent curves composed of combined arcs the greatest care is necessary, so that the one may glide smoothly into the other without showing any break or thickening at the joining. To describe the Cyma Recta shown in Fig. 117, which is the form most generally used, let *n* and *o* be the points to be united by the moulding. Draw the line *n o*, and bisect it; with half *n o* as a base describe an equilateral triangle on the opposite sides of the line; then the apices* of the triangles will be the centres from which the curves are to be struck.

To describe Fig. 118, or others the curves of which are required to be more flat than in the last figure, draw the line *n o* as before, and bisect it. Bisect these two divisions again, and the centres will be on these bisecting lines, according to the form required; for, of course, the longer the radius the flatter the curve will be.

If it is required that the curve should be more full at the lower than at the upper part, it may be effected in the following manner, which is shown in Fig. 119. Having drawn *n o*, divide it into *three* equal parts; construct an equilateral triangle, the base of which is two of these thirds, and on the opposite side of the line another, the base of which is the remaining third. The apices of these triangles will be the centres for the curves.

Fig. 120 is the *Cyma Reversa*. In this moulding the curve bulges outward at its upper part, its fulness being regulated by the taste of the designer. Thus it may be formed of two quadrants, as in Fig. 120; or of two semicircles, as in Fig. 121; or it may consist of the two arcs drawn from the apices of triangles, as in the cyma recta already shown.

Fig. 122 is the *Scotia*. This is a hollow moulding, sometimes consisting of a semicircle only—viz., the reverse of the torus. In other instances, as in Fig. 122, it is composed of two quadrants; and in others it is drawn from three centres, as in Fig. 123. To draw this, divide the depth of the moulding into three equal parts, and with one third describe the quadrant *r u;* produce the horizontal *r u*, and from *r* set off *i*, equal to half *u r*. At *n* erect a perpendicular, and mark on it *n k*, equal to *i u;* draw *i k*, and bisect it; produce the bisecting line until it cuts *n k* in *s*. Draw *s i*, and produce it. From *i*, with radius *i u*, draw the next portion of the curve, meeting *s i* produced; then complete the curve by an arc drawn from *s* with radius *s n*.

A fillet (from the French word *filet*, a band) is the small flat edging used to separate two larger mouldings, to strengthen their edges, or to form a cap or crowning to a moulding. The fillet is one of the smallest members used in cornices, architraves, bases, and pedestals. When placed against the flat

* *Apices*—plural of *apex*. The upper point of a triangle.

surface of a pedestal, it is usually joined to it by a small quarter-round hollow called the *Apophyge* (Fig. 124).

The torus, when worked very small, is called the *Astragal* (Fig. 125); but when worked so as not to project, as on the edge of boards to be joined, it is called a *bead*.

Figs. 126 to 133 are sections of *Gothic* mouldings. The whole of the construction lines are given in the illustration, and it is hoped the student will be able to work from these without any further aid. The whole subject of "Gothic Architecture" will be fully treated of in a separate series of lessons.

FREEHAND DRAWING FOR JOINERS.

We now proceed to give some examples of free-hand drawing, which we are sure will be acceptable to the student. In these examples Figs. 134 and 135 are studies of the wave-line. They are, in fact, the cyma recta repeated, the depth being lessened in Fig. 135.

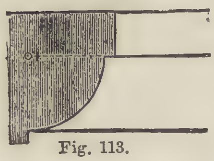


Fig. 113.

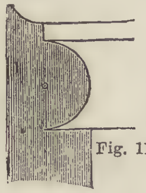
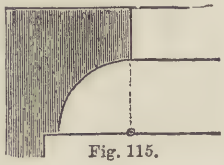


Fig. 114.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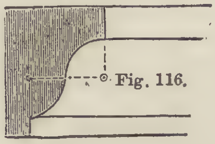


Fig. 116.

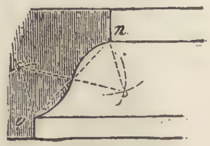


Fig. 117.

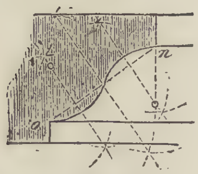


Fig. 118.

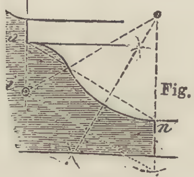


Fig. 119.

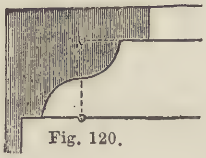


Fig. 120.

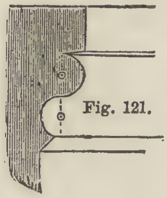


Fig. 121.

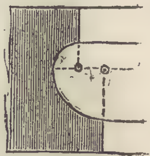


Fig. 122.

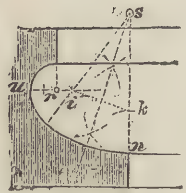


Fig. 123.

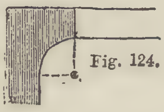


Fig. 124.


Fig. 125.

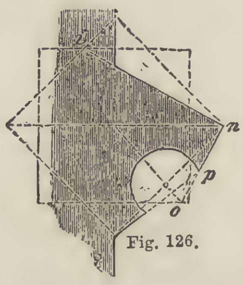


Fig. 126.

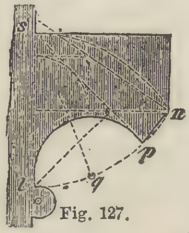


Fig. 127.

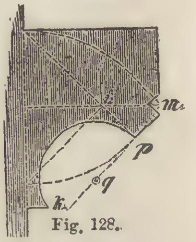


Fig. 128.

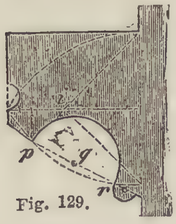
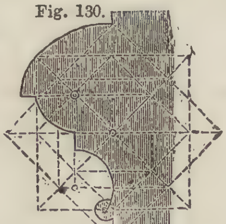


Fig. 129.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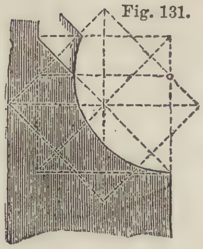
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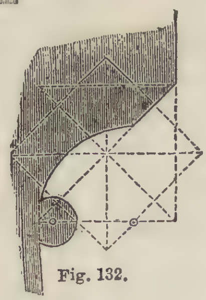


Fig. 132.

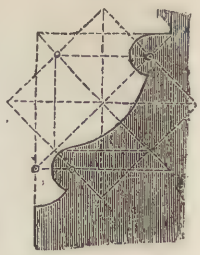


Fig. 133.

Fig. 136 is a study of the elementary lines of a running scroll, formed of the wave-line, with the addition of spirals. Care must be taken in drawing these spirals, so that they may proceed from the stem in a smooth and continuous manner. They should start as a continuation of the wave-line so gradually, that if the stem beyond the spiral were removed, the scroll would be perfect, and that if the scroll were taken away the wave-line would remain uninjured. This should also be the case in Fig. 137, in which tendrils are added to the scrolls.

Fig. 138 is a further elaboration of the same design, the lines being doubled.

Fig. 139 is another simple running pattern based on the wave-line.

Figs. 140 and 141 are ancient borders worked on the ogee or cyma reversa moulding. These are both to be started in the same manner as Figs. 143 and 144—namely, by dividing the width into equal parts for the middle line of the arch or of the tongue, and dividing each space again to obtain the middle line of the dart or flower. The main forms are then to be sketched in.

Fig. 142 is the *Guilloche*, or chain, and is formed by concentric circles overlapping each other. This pattern is easily drawn with compasses, but is here given as a freehand study, in order to give the student an exercise in severity and accuracy of form.

Fig. 143 is a Greek border, composed of a leaf and dart, and is presented, of course, with the understanding that it is to be copied on a very much larger scale; and the student is again reminded that shading must be secondary to outline, and that therefore it is intended that each of the studies here given is to be drawn *twice*, first, as distinct practice in *outline*; and, secondly, another outline having been drawn, the shading may be added, but on no account is the shading to be begun until the outline can be drawn with facility. In commencing to draw this moulding, which is used as a decoration for the cyma reversa, set off the widths of the leaves, and draw perpendiculars, which will afterwards be the middle lines for the darts or tongues. Exactly in the middle of each of these spaces draw other perpendiculars for the midribs of the leaves. The curves are next to be drawn, being careful to balance the sides accurately.

Fig. 144 is the Greek ornament known as the *Egg and Tongue*. It is used as a decoration for the ovolo moulding. The method of commencing to draw this is the same as in the last example, and thus any further instructions are unnecessary.

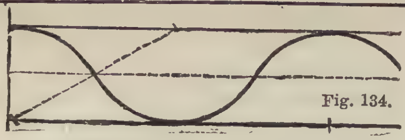


Fig. 134.

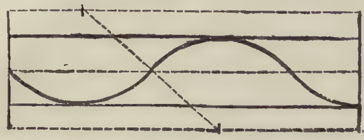


Fig. 135.

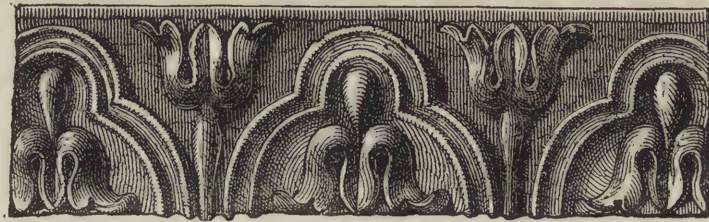
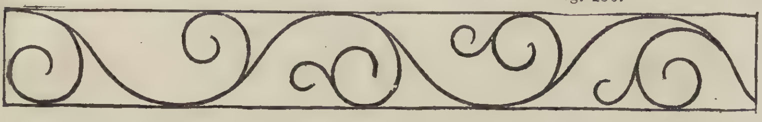


Fig. 140.

Fig. 136.



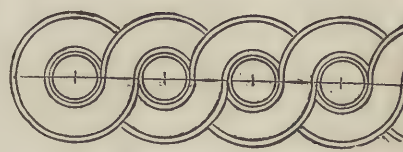
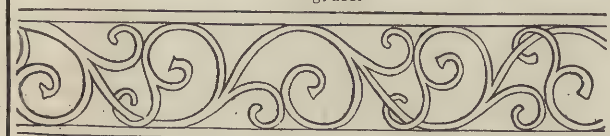


Fig. 142.

Fig. 137.

Fig. 138.



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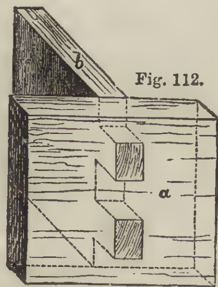


Fig. 112.

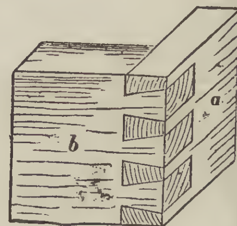


Fig. 109.

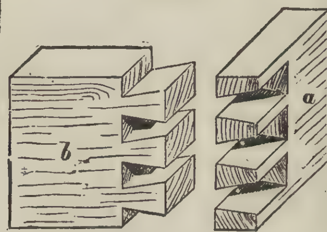


Fig. 108.

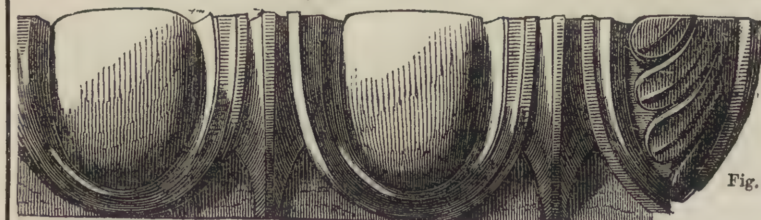


Fig. 144.

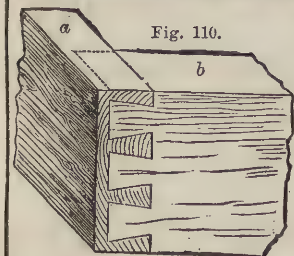


Fig. 110.

Fig. 143.

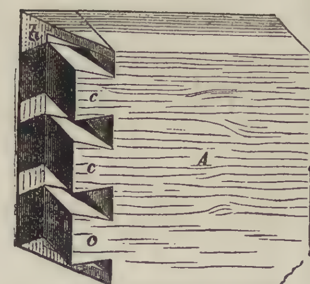


Fig. 111.

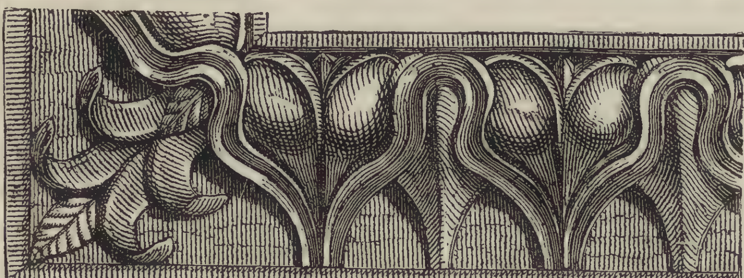
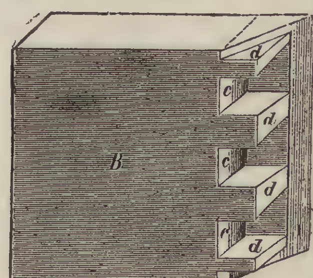


Fig. 141.



TECHNICAL EDUCATION ON THE CONTINENT.—VII.

BY ELLIS A. DAVIDSON.

THE PARISH WORKMEN'S SCHOOLS OF WURTEMBURG.

The workmen's schools of the kingdom of Wurtemburg afford, as a complete series, an admirable example of a great system by which thousands of young people of both sexes receive instruction, such as may qualify them for entering on a future course of usefulness, and at the same time assist in developing the elementary instruction which they have received in the primary schools.

These schools, admirably organised as they are, fulfil, however, a moral as well as an intellectual mission. It is just in the years when a boy leaves the primary school and goes to business that he begins to feel the desire to throw off the trammels which school discipline has during his early life imposed upon him. He enters a workshop; is associated with other youths and men; he earns money, and learns to spend it; he acquires habits of manliness—not always such as add dignity to that term; and thus in these few years the whole moral status of the youth is decided.

It is in watching over this critical period of a boy's life—in attaching him to the studies, the elements of which he as a child acquired—in showing him the advantages and the application of the rudimentary instruction he has received, that these schools acquire a charm and exercise an influence over the whole future life; whilst by the practical teaching of the "Realschulen" (*real* schools, an admirable name), the "Gewerbeschulen" (trade or industrial schools), the "Fort-bildung schulen" (*continued* education schools), and the "Bau-gewerke schulen" building (and the trades connected therewith) schools, the scientific branches of the boy's future employment are thoroughly taught, and he enters the workshop, not a mere looker-on or errand-boy, but understanding the constructive principles of the work going on, and in some cases with a fair amount of manual skill.

The original promoters of these schools said, "It is, no doubt, a matter of great importance that in universities and academies professional men have an opportunity of acquiring every kind of scientific instruction" (would that this could be said of England); "but a task has in these days become one of urgent necessity—namely, that of providing for the rising generation of the working and trading classes, not only the elementary knowledge offered in primary schools, but also that amount of technical and scientific instruction which tradesmen now require, in consequence of the increased competition amongst themselves and between tradesmen and manufacturers, as also in consequence of the improving taste of the public, and the great improvement made in all the different branches of industry."

The claims of the present age in regard to education have been well understood in Wurtemburg. As far back as 1818 a step was made in the direction indicated, by introducing into the Sunday-schools already established in the larger towns, for youths who had left the primary schools, special classes for drawing for apprentices. It is needless to say that such a step is *not* one advocated in these papers.

Afterwards, however, preparations were made by the Board of Education for extending the principle to a greater number of schools. But it was in 1848 that the actual organisation of the "working men's schools," as they are at present, was carried out, when the newly-created Board of Trade and Industry was charged also with the care of providing good instruction for the youths engaged in workshops and trade generally.

To effect the latter purpose, a special commission, composed of members of the above-named body, was appointed. This commission, standing in direct communication with and in subordination to the Ministry for educational matters, could not, however, turn to any enactments which would have empowered them to order parishes to establish the schools required; and it was thus only by way of recommendation, and by treating with such of the parishes which had shown an interest for the subject in question, that they could hope to succeed. They were, however, much aided in their efforts by the circumstance that pecuniary means were liberally granted by the State, in the form of subsidies, to such schools as had been organised in conformity with the conditions fixed by the commission, the sums granted in this way amounting in general to half the yearly expenditure made by the parishes themselves for the support of the said schools, thus assisting but not superseding local effort.

The conditions chiefly insisted upon by the commission in the organisation of the schools were, in the first place, the voluntary principle with respect to the frequenting of the schools, and the demand that fees should be paid by the scholars—a demand which, however small the fee might be, was considered of importance with regard to the well-known fact, that what is paid for is more appreciated than that which is given gratuitously. Thanks to the enlightenment of the Government and the ready assent given by the Chambers, the pecuniary means placed at the disposal of the commission were soon increased, and through the additional aid afforded by a large collection of educational works and appliances, maintained out of the funds of the Royal Board of Trade and Commerce, the commissioners had the satisfaction of seeing their efforts crowned with much success.

The principal task of the commissioners is to take measures that suitable localities, and all the necessary means of education, such as good books, models, diagrams, etc., are provided for the schools; to control the appointment of the managing boards and inspectors, as well as the training up of good teachers of drawing, etc.

The commission did not, however, think it advisable to organise all the schools after a uniform system, feeling that regard must be had to the different circumstances of each locality; and therefore the general plans of some of the leading schools will be given in these papers, in order that the diversities may be rendered clear to the reader.

The 135 schools now in existence in Wurtemburg (of which a statistical notice will be given further on) present, of course, various degrees of development, the studies being adapted to the requirements of the locality. In many of the smaller towns and villages the instruction is confined to arithmetic as adapted for trade purposes, commercial correspondence, composition, and drawing; this last subject, however, is in every case divided into geometrical, free-hand, and trade drawing, adapted to the wants of the district. Thus in Stuttgard the branches of drawing taught are especially those adapted for the work of builders, carpenters, locksmiths, saddlers, etc. Of course, the progress made by pupils must in a great measure depend upon the amount of elementary knowledge they have acquired in the primary schools, the purpose of these schools being supplementary, not rudimentary.

The schools are open to persons of all creeds without distinction, and the Government insist that they shall be established in every town or village, however small, where trade of any kind is carried on. But the attendance of the pupils is not compulsory; on the contrary, only such as can produce testimonials of good conduct and industry are admitted, and indolent, irregular, and badly-conducted pupils, since they necessarily impede the progress of others and set a bad example, are dismissed.

The examples used in the drawing-schools are of a large size, and are of an eminently practical character, adapted for almost every branch of construction and decorative industry.

The practical work done in these schools is, considering that it is executed by youths, truly satisfactory. It consists of models of machinery, buildings, and roofs, scientific apparatus, furniture, etc. In the art schools, excellent drawing from the flat and round is carried on, together with modelling in wax and clay; casting figure and ornament in plaster; metal work, chased and hammered; carving in wood, etc. etc. The whole system, carried out under able and experienced teachers, shows to the utmost advantage the practical application of technical education.

THE COMMERCIAL TRADE SCHOOLS.

These are designed to enable young persons of either sex to obtain those branches of theoretical and practical education which may be required in their trade, occupation, or domestic management.

Those entering as pupils must have completed their fourteenth year, and the males must previously have had some practice in manual work.

The instruction in the Trade Schools is given in the hours after the close of business, and for the special accommodation of workmen whose trades are only carried on in fine weather—as bricklayers, painters, slaters, etc.—day-classes are established,

so that an opportunity is afforded for them to improve their education without losing wages; and they are encouraged to come to the schools when not employed in their work, instead of lounging about in the manner so often and so painfully seen in this country.

The course of study in these schools comprehends geometrical and free-hand drawing; practical art adapted for special branches of industry; arithmetic; elementary geometry; trigonometry and algebra; stereometry; commercial and trade accounts; composition and correspondence; book-keeping; French, English, and Italian languages; elementary chemistry and physics; natural history; physiology applied to health; sanitary knowledge; domestic accounts and household management, the whole of the studies having reference to the present and future occupation of the learner, according to various necessary rules and regulations which will be given in connection with the individual schools.

The Parish Workmen's Schools of Wurtemburg may be divided into four classes, viz.:—

1. Commercial schools; in which the instruction afforded is intended chiefly for the benefit of merchants, bankers' clerks, and others engaged in trading and commercial pursuits of all kinds.

2. Trade schools; in which the teaching afforded is adapted for artisans generally.

3. School of practical art; for ornamentists, designers, art-workmen, and teachers.

4. Female school; to give instruction to girls and young women in domestic economy and household management—a description of school much required in this country, artisans' wives, as a rule, not possessing much sound knowledge in these matters.

Students above the age of sixteen have the privilege of electing from amongst themselves a "captain," who in all matters represents the class. He acts as deputy before the arrival or in the absence of the teacher, whom he also supports and assists when present. These monitors are chosen from the Upper School, and must be above the age of eighteen. The students must, however, consult the teacher as to whether he wishes such assistance or not.

In order to test the progress and to reward the perseverance and industry of the students, periodical exhibitions are held, when certificates, prizes, and other rewards are awarded, which are highly valued by the recipients, and prove a considerable stimulus to exertion and honourable competition among the members of the various classes.

Although architecture and engineering, and the courses of study they require, have been principally mentioned, it must be understood that the technical instruction takes the widest range, including all the practical arts, and embracing the whole range of manufactures; this will, perhaps, account for the repeated reference to the union of science and art. In carrying out this scheme the assistance of skilled workmen is obtained; and, further, persons, whether male or female, professing and carrying on various trades, are invited, not only to visit the school and advise, but also to attend at regular and special hours. They are then entitled, should they require remuneration, to receive payment from the State according to a fixed tariff. By this means not only are the advantages of experience obtained, but the sympathy of the class who are employers of skilled labour is cultivated.

In this regard we should not be wanting in this country. The noble example set by Sir Joseph Whitworth in the furtherance of technical education, and the munificent amounts he has devoted to it; the active measures taken by the late Herbert Minton in the promotion of education amongst his employés, and the liberality with which our leading manufacturers contribute not only money but practical aid in the support of any institution for the benefit of our working men, prove that if they show themselves desirous for a proper and extended system of education for themselves and their children, they will find plenty of co-operation. Thus this great country, so universally quoted for its liberality of sentiment, will at no very distant period make such strides in the training of her workmen as will enable her, by the united efforts of her own sons, to hold her own against the whole world; and thus as the merciful Creator allows his light to shine as brightly into the pitman's hovel as into the nobleman's mansion, the work will prosper to the glory of His name and the honour of our native land.

ANIMAL COMMERCIAL PRODUCTS.—IX.

PRODUCTS OF THE CLASS AVES.

Birds are warm-blooded, vertebrated animals, characterised by a double circulation and respiration, the adaptation of their anterior extremities for flight, oviparous reproduction, and a covering of feathers. The following classification, founded on certain modifications in the structure of the beak and foot, is that which is generally adopted by naturalists:—

1. *Raptores* (Latin, *raptor*, a robber), or birds of prey, having a strong, curved, sharp-pointed beak, short robust legs, and a foot furnished with three toes before and one behind, which are armed with long, strong, crooked, and more or less retractile talons, adapted to seize and lacerate a living prey. Examples: eagle, hawk, and vulture.

2. *Insessores* (Latin, *insideo*, I sit on), or perching birds, having three toes before and one behind, slender and flexible, with claws, long, pointed, and slightly curved; a foot, in fact, organised and adapted for the delicate operations of nest-building, grasping the slender branches of trees, and perching on them. Examples: sparrow, robin, and crow.

3. *Scansores* (Latin, *scando*, I climb), or climbing birds, with the four toes arranged in pairs, two before and two behind—a conformation of the foot most suitable for climbing trees. Examples: woodpecker, cuckoo, and parrot.

4. *Columbidæ* (Latin, *columba*, a pigeon), including pigeons and doves.

5. *Rasores* (Latin, *rado*, I scratch), or scratching birds, having three toes before and one behind, strong, straight, and terminated by robust, obtuse claws, adapted for scratching up the soil. Examples: turkey, pheasant, partridge, and the common barn-door fowl.

6. *Cursores* (Latin, *curro*, I run), or running birds, with wings unfitted for flight, and feet formed for running swiftly over the ground, with two and sometimes three toes in front, and none behind, except in the apteryx. Examples: ostrich and cassowary.

7. *Grallatores* (Latin, *grallator*, a stalker), wading birds with long legs, the three anterior toes long and slender, and the posterior toe elevated and short—a form of foot and leg which enables the bird to seek its food in water along the margins of rivers, lakes, and seas. Examples: crane, heron, sandpiper.

8. *Natatores* (Latin, *natator*, a swimmer), swimming birds, including those which have the toes united by an intervening membrane. The body is protected by a dense covering of feathers, and a thick down next the skin; the whole organisation is adapted for aquatic life. Examples: duck, swan, and goose.

The products of the class Aves consist of

FOOD.

All these orders of birds, with the exception of the first, afford flesh which may be eaten. The eggs of many of them are very nutritious, especially those of the Rasorial birds: 397,934,520 were imported from France in 1867. In one case, even the nest is available as food—namely, the Chinese edible birds' nests, constructed by a Javanese swallow. The collecting of these nests employs numbers of people, as they are largely exported to China from Java, Ceylon, and New Guinea. It is calculated that 30,000 tons of shipping are engaged in this traffic, and that the value of their freights is above £280,000. But the chief commercial value of birds lies in their feathers.

FEATHERS.

A feather consists of three parts—the quill, the shaft, and the vane. The quill is that part of the feather by which it is attached to the skin; it is cylindrical, hollow, and semi-transparent, possessing in an eminent degree the qualities of lightness and strength. The shaft is covered by an outer layer of firm, horny material, like that which forms the quill, and encloses a soft elastic substance called the pith. The vane consists of barbs and barbules. The barbs are attached to the sides of the shaft, the barbules are given off from either side of the barb, and when long and loose they characterise the form of feather known as a "plume"—*e.g.*, that of the ostrich, which, commercially considered, is the most valuable of feathers. The development of feathers is always preceded by that of down, which constitutes the first covering of young birds. Their colours are due to peculiar organic pigments, which may

be separated by appropriate solvents. The beautiful play of colours shown by some feathers is referable to a decomposition of light, analogous to that produced by mother-of-pearl, and other striated surfaces.

The preparation of feathers for military decoration, or for the toilette, forms the art of the plumassier, the French term for the artisan who works on them. Feathers may be dyed a variety of beautiful colours, and of these, rose-colour or pink is given by safflower and lemon-juice, and deep red by a bath of Brazil wood boiling hot, after aluming; indigo supplies the blues of every shade, and turmeric the yellows, alum being the usual mordant.

Ornamental Feathers.—The most valuable and esteemed ornamental feathers are, unquestionably, those of

The Ostrich (*Struthio camelus*).—The elegance of these feathers arises from their slender stems and disunited barbs. Those taken from the living or from recently killed birds are far more beautiful than the cast or dropped ones. The feathers from the back and above the wings are the best; next, those of the wings and tail. Ostrich feathers dyed black—for which purpose logwood, copperas, and acetate of iron are used—are sold to undertakers as mourning plumes; a full set is worth from £200 to £300. Ostrich feathers are scoured with soap, and then bleached. Fine white ones are worth from seven to eight guineas a pound. The finest white feathers of this bird, which is indigenous to Northern and Central Africa and Arabia, come from Aleppo in Syria. Good ostrich feathers are also received from Algiers, Tunis, Alexandria, and Cairo, and inferior ones from Senegal and the island of Madagascar.

The *Little Egret* (*Herodias leuce*) is found in all the countries on the Mediterranean coast, and in Asia as far as the East Indies; an allied species, *H. œgretta*, is a native of tropical America. The feathers of both species are of the purest white, very delicately formed, six or eight inches in length, with slender shafts. The Turks and Persians embellish their turbans with them, and they form plumes for ladies' head-dresses in this country and on the Continent.

The *Great White Heron* (*Ardea alba*) inhabits the shores of the Caspian, the Black Sea, and lakes of Tartary, and is also found in America and Africa. The largest and most expensive white heron feathers are furnished by the plumage of this bird.

Common Heron (*Ardea cinerea*).—The black heron feathers are supplied by this species, which is found throughout Europe, but especially in Prussia, Poland, and Russia. We receive the greatest quantity from Siberia.

Adjutant (*Leptoptílis Argála*), and a kindred species (*L. Marabou*), furnish the exquisitely fine and flowing plumes termed "Marabou feathers." The former species is the well-known scavenger bird of India, its name being derived from its habit of frequenting the parade-grounds; the latter is a native of Africa.

It is impossible to enumerate all the birds whose beautiful plumage supplies us with ornamental feathers. The feathers of the Bird of Paradise, the gold and silver pheasants, the peacock, the several species of *Ibises*, the flamingo, the beautiful wing and tail feathers of the Argus pheasant, and the wing of the partridge and ptarmigan are all worn in children's and ladies' hats. Cocks' feathers furnish plumes for soldiers; eagles' feathers are worn in the hat and bonnet in Scotland, and a plume of them is a mark of distinction amongst the Zulus in South Africa. The wing and side feathers of the turkey supply trimmings for articles of ladies' apparel, and are made into victorines, boas, and muffs.

Artificial flowers made from feathers are now much worn by ladies. The feathers selected for their manufacture are chiefly those of a purple, copper, or crimson colour, from the breasts and heads of humming-birds.

Feathers are also worn as articles of clothing. The skin of the swan, after being properly prepared, is used for muffs, linings, and a variety of other articles of dress; the skin and feathers of the penguin, puffin, and grebe (*Podiceps cristatus*) are worn as clothing on account of their beauty and warmth, supplying suitable material for victorines, tippets, boas, cuffs, and muffs, and other articles of winter attire. The native inhabitants of the Arctic regions, in some parts, make themselves coats of bird-skins, which are worn with the feathers inside. Confucius, the Chinese philosopher, writes, that ere the art of weaving silk and hemp was understood, mankind used to clothe themselves with the skins of beasts and with feathers; and it is very certain that the Chinese are now very skilful and ingenious in the art of plumagery or feather-working. They manufacture garlands, chaplets, frontals, tiaras, and crowns of very thin copper, on which purple and blue feathers are placed with much taste and skill.

PROJECTION.—IX.

PENETRATIONS OF SOLIDS (*continued*).

FIG. 105 is the plan and elevation of a square prism, penetrated at its *edges* by a smaller prism, their axes being at right angles to each other. Having drawn the square A B C D—the plan of the larger prism—draw the line E F through the centre, and make it equal to the required length of the smaller prism. At F draw J K, and at E draw G H, equal to the diagonal. On G H construct half the square of the end—viz., produce F E until E I equals E H, and join I H and I G. Draw H J and G K. These will complete the plan of the smaller prism, which will penetrate the sides of the plan of the larger prism in L M N O. Project the elevation C A D of the larger prism from the plan, and draw G′ K′ at right angles to the axis. On each side of G K set off the length E I—viz., points E, E; F, F. Draw perpendiculars from L and M, cutting G′ K′ in L′ M′. Join C L′ C, D M′ D, which will be the lines marking the intersections of the two prisms.

Fig. 106 shows the projection of this object when the axis of the smaller prism is at an angle to the vertical plane.

Fig. 107 is the development of the longer prism, showing the shape of the openings through which the smaller prism is to pass. On a straight line set off four times the width of the side of the plan represented by A D B C A. Erect perpendiculars from these points equal to the height of the prism, and draw a horizontal line at their extremities. Produce E F, G′ K′, and E F, to cut line C in P Q R, and line D in P′ Q′ R′. On each side of Q set off Q S and Q T, equal to C L in the plan, and set off the same measurement—viz., Q′ S′ and Q′ T—on each side of Q′. Join P S R T, and also P′ S′ R′ T′, and two lozenge-shaped figures will be formed. It will be observed that these are wider across than the prism which is to pass through the aperture, but it must be remembered that the two sides of the larger prism are bent at right angles to each other, and thus, when the perpendiculars A and B are brought together, S and T approach each other until the distance between them is equal to M N in the plan, which, it will be seen, corresponds with the diagonal of the end of the smaller prism.

Fig. 108 is the development of one of the projecting ends of the smaller prism. Here the widths are taken from G I in the plan of the smaller prism (Fig. 105), and the heights from D F, J O, M K.

PLAN AND ELEVATION OF A CYLINDER PENETRATED BY A SMALLER ONE.

The circle in the lower plane (Fig. 109) represents the plan of the larger, and the parallelogram D D′ E′ E that of the smaller cylinder. From this figure project the mere cross which forms the elevation. No explanation of this process is deemed necessary, the object of the lesson being to find the curve generated at the points where the penetration takes place. The student is here reminded that, as the plan is the view of the object when *looking down* upon it, the line C A B C′, which is the top line of the smaller cylinder in the elevation, is the *middle* line in the plan; and thus the line D E, which is the front or most prominent line of the cylinder in the plan, is represented by D E, the middle line in the elevation.

From C′ in the plan, with radius C′ E, describe a semicircle, which represents half of the plane of the end of the cylinder. This plane, although laid down flat, is supposed to stand upright on the line E E′ at right angles to the plan. Divide the semicircle into any number of equal parts, and from these divisions draw lines meeting E E′ at right angles in F and G. Set off the lengths of these perpendiculars on each side of the line D E in the elevation—viz., F F and G G, and draw lines from these points across the whole length of the elevation of the smaller cylinder. Draw similar lines parallel to C C′ from the corresponding points in the plan—viz., F F′, G G′, which lines will be seen to pass, not only through the smaller, but

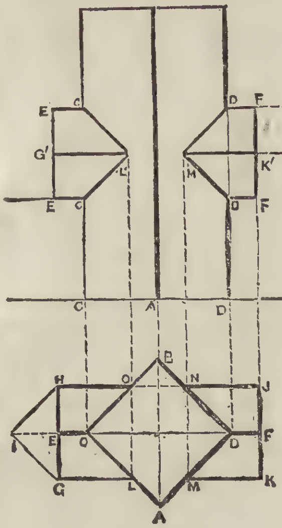


Fig. 105.

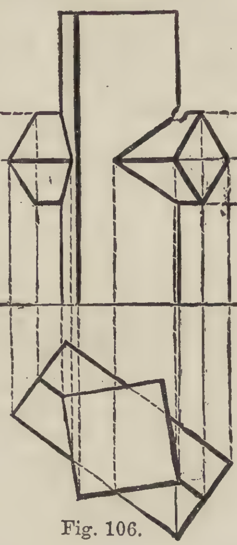


Fig. 106.

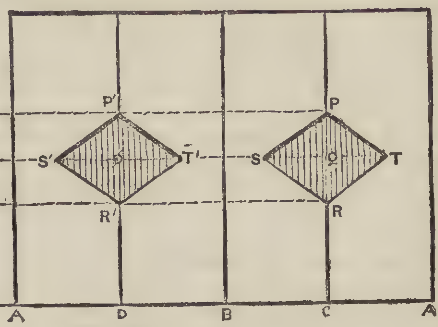


Fig. 107.

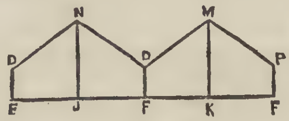


Fig. 108.

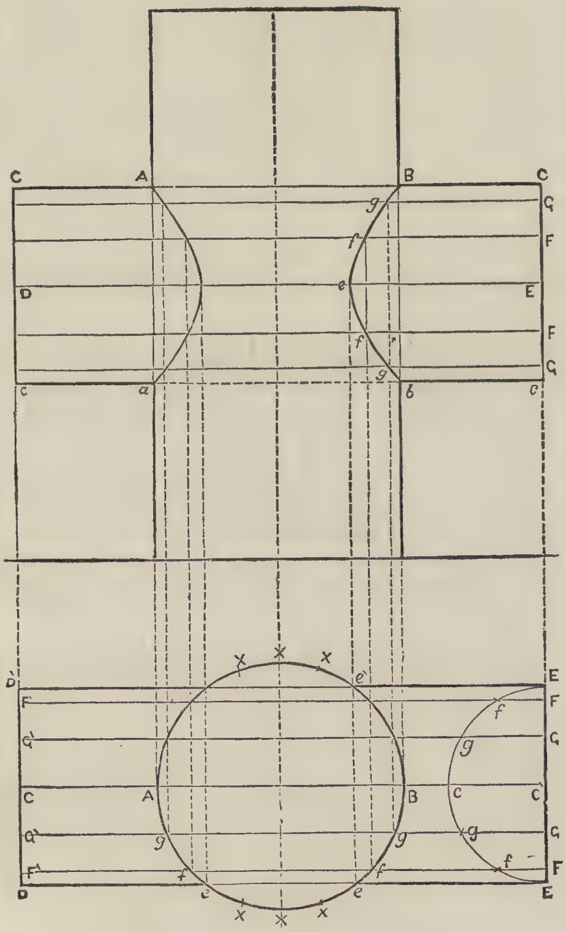


Fig. 109.

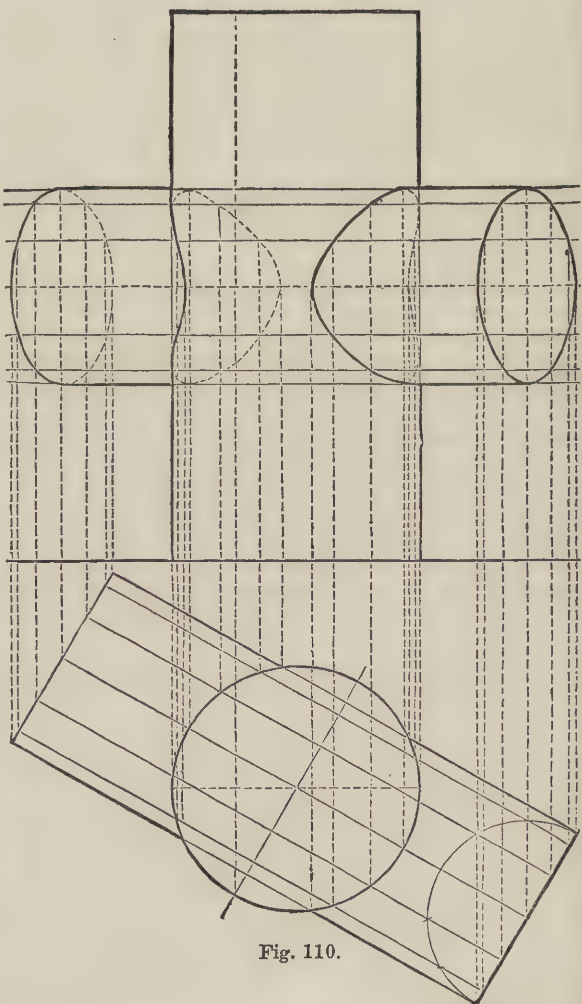


Fig. 110.

also through the larger cylinder, representing as they do planes common to both the solids. From the points A and B, *f g e*, draw perpendiculars to meet the horizontals drawn from the points similarly lettered in the elevation, and the intersections *e*, *f f*, *g g* will give the points through which the curves of the penetrations are to be drawn.*

Fig. 110 shows the projection of the objects when the plan has been rotated, so that the axis of the smaller cylinder is at an angle to the vertical plane. The lettering is omitted, but as all the lines of construction are shown, it is hoped that the student will be able to project the object with the aid of the instructions here given. It has repeatedly been shown that when an object is simply rotated on its axis, or on a solid angle, without altering the inclination, the *heights* of the various points will remain the same. This fact may be observed in a crane. When the weight has been raised as high as may be required, the crane is rotated, but the height of the top and of the weight will be exactly the same in which direction soever the crane may be turned, and thus the piece of ground overhung by the crane and weight will remain *the same in form though altered in position.* If, therefore, the plan and elevation given in Fig. 109 has been prepared, it will only be necessary to repeat the plan, placing the axis of the smaller cylinder at the required angle; then perpendiculars raised from the various points in the plan may be intersected by horizontals drawn from the corresponding points in the elevation, and the intersections thus obtained will give the points required for the projection.

But, in practice, the whole of the object shown in Fig. 110 might be projected without referring to the previous one, and it is important that the student should understand this, as otherwise time would be lost. To project the object when at any angle, therefore, proceed in the following manner:—Draw the circle which represents the plan of the larger cylinder. Draw a line through the centre of this, making an angle with the intersecting line corresponding to the angle which the axis of the smaller cylinder is to make with the vertical plane. On this line set off, on each side of the centre, half the length of the smaller cylinder, and at these points draw lines at right angles to the line of the axis. The plan of the object will then be complete, and we proceed to project the elevation from it. Draw a fine or dotted line through the centre parallel to the vertical plane, and from the extremities of this diameter carry up the perpendiculars which are to form the edges of the elevation of the larger cylinder. Now it must be borne in mind that these are *not the points from which the elevation of the cylinder would be projected if the axis of the smaller one were parallel to the vertical plane.* In that case the perpendiculars would be raised from the points where the axis of the smaller cylinder cuts the circumference of the plan of the larger one; but if this were done in the present position of the plan, the elevation would be *narrower* than the cylinder. All vertical sections of a cylinder are parallelograms, and all those which pass through the centre are equal. Still, reference to Fig. 8 (page 9) will remind the student that the real size of a plane is only obtained in the elevation when it is parallel to the vertical plane; and it will be seen that the elevation of the plane, of which the diameter of the plan, which is *at an angle* with the vertical plane, is the elevation, would not therefore be the projection of the largest section, and would not represent the true width any more than the elevation of the open door in Fig. 11 (page 24) represents its real width, and it thus becomes necessary to draw the dotted line referred to, so that the elevation may represent the *greatest* width of the cylinder. Now draw another diameter in the plan at right angles to the axis of the smaller cylinder, and the extremities of this line will be the front and back lines of the larger cylinder, which, if the axis of the smaller one were parallel to the vertical plane, would be the centre of the elevation; but as it has of course rotated with the object, it is central no longer, but its relation to the heights remains the same, however the larger cylinder may be turned on its axis.

On this perpendicular, therefore, set off from the intersecting line the real height, and draw the horizontal line, which represents the top of the larger cylinder.

Mark on the perpendicular, too, the height at which the axis of the smaller cylinder intersects that of the larger, and draw a horizontal through the point.

Returning now to the plan, the preparation for the projection of the circular end of the smaller cylinder, as shown in Fig. 77, is necessary. On the line which forms the end in the plan draw a semicircle, and divide it into any number of equal parts. Through these points of division draw lines parallel to the axis of the smaller cylinder, which will be seen to pass through the plan of the larger one, and the intersections will be the plans of points "common to both" cylinders.

Now, from the points where these lines meet the straight line, which is the plan of the end of the smaller cylinder (on which the semicircle has been drawn), raise perpendiculars passing through the horizontal line which has been drawn across the elevation, and above and below this horizontal set off on the perpendiculars the *lengths of the lines drawn from the points in the plan from which they started* to the semicircle. Join the points thus obtained, and the projection of the end will be obtained. From each of the points through which the ellipse has been drawn now draw horizontal lines, and raise perpendiculars from the points in the opposite end of the plan; the curve of the end of the smaller cylinder which is turned away must then be traced through these points, and it will be observed that, as only one side of the ellipse could really be seen in this position of the object, the other half is drawn in dots. It now remains to find the shape of the curve of penetration—that is, the curve generated where the smaller cylinder penetrates the larger, and this will be accomplished by finding the elevations of the points which in the plan were spoken of as "common to both" cylinders. From these points —that is, from the points where the lines drawn parallel to the axis of the smaller cylinder cut the circle, which is the plan of the larger one—erect perpendiculars cutting the horizontal lines in the elevation, which are in fact the elevations of the lines in the plan. The curves must then be traced through the intersections of these two sets of lines. The perpendiculars must be drawn not only from the points on the front of the plan, but from those on the back part, and these cutting the horizontals will give the points through which the curve on the other side of the cylinder is to be drawn.

The reason why the perpendiculars at the back are to cut the same horizontals as those in the front, is that already pointed out—viz., that a point is not altered in height when the object on which it exists rotates on its axis in the manner shown in the diagram.

APPLIED MECHANICS.—IV.

BY ROBERT STAWELL BALL, M.A.,

Professor of Applied Mathematics, Royal College of Science, Dublin.

THE CRANE.

INTRODUCTORY—THE FRAMEWORK—THE WHEELWORK.

In the various operations connected with manufactures, and with the transport of goods from one place to another, it frequently becomes necessary to raise weights and carry them about. When the weights are large, amounting as they often do to many tons, special mechanical appliances have to be used. It is our intention in this lesson to examine into some of the machines used for this purpose.

In unloading a ship at the quay-side, some heavy weight—such, for example, as a block of marble weighing ten tons—must first of all be lifted from the hold. It must then be carried from the ship to the quay, and there be deposited in safety. The machine which is able to accomplish this must have three distinct properties. In the first place, it must be a sufficient mechanical power to overcome the resistance. In the next place, it must be sufficiently strong to sustain the load suspended from it; and in the third place, it must be capable of moving the block, when suspended, from the ship to the quay. These three requisites are very beautifully combined in the useful machine known as the *lifting crane.* With its powerful aid three men would be easily able, at the cost of a little time, to unload the block of marble, even though it weighed ten tons. We shall consider the several parts of a crane separately, and show how each is adapted for the work it has to perform; we shall then describe some forms of crane which are used for various purposes in the arts of construction.

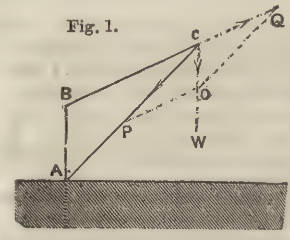
* The points *x*, *x*, *x* are not used in this projection, but will be subsequently referred to.

THE FRAMEWORK.

The form of crane which is most familiarly known is that which is sometimes called the *jib-crane*. It is in reality a triangle, one side of which is held vertically, while the load is suspended from the opposite vertex. The framework of this crane—with which alone we are at present engaged—is represented in Fig. 1 in a diagrammatic manner. ABC is a triangle of which the side AB is held constantly vertical, while the load is suspended from the vertex C.

We shall first endeavour to ascertain the nature and amount of the strains along the different parts of this structure. A knowledge of these strains is quite essential to a complete understanding of any machine. By this inquiry the proportions of the different parts can be properly adjusted, so that failure of strength on the one hand, or, what is also very undesirable, extravagant waste of material on the other, may be equally avoided.

Fig. 1.



In Fig. 1, W is the position of the suspended weight. If I take a length, CO, which is proportional to the magnitude of W, and place an arrow to indicate the direction of the force, the line CO represents the force, as explained in the first lesson in "Mechanics" (POPULAR EDUCATOR, Vol. I., page 17). Now this force CO must be supported by BC and AC, and therefore there must be certain strains acting down these lines. In order to find them, draw OP parallel to BC, and OQ parallel to AC. Then by Lesson III. ("Mechanics") the force OC can be decomposed into two forces, CP and CQ. The directions of these forces are indicated by the arrows: that along CA is a force of compression, that along CB is a force of extension. Since OC and OP are parallel to AB and CB, the triangle OCP is similar to the triangle ABC, and hence the forces OC, CP, and CQ are proportional to the sides of the triangle ABC. If, therefore, the load be represented by AB, the strains along BC and AC are represented by their lengths.

The line BC is in a state of tension; that is, the force is tending to tear it asunder. Now a force of this kind is called in mechanics a "tie," and the amount of the force which is straining is called its tension. On the scale of the figure the line BC is double AB, and hence the tension of BC must be double the load. If, then, the crane were employed in raising a load of ten tons, the tension along BC would be twenty tons, and the tie must therefore be strong enough to bear this amount. But in constructions of this kind it is not sufficient that a piece be just sufficiently strong to bear the strain it has to carry: we must always allow a very considerable margin. This is especially true in a machine like a crane, which is subject to countless jerks and shocks, which for a moment place a far greater strain upon its parts than would be produced by the mere load it supports. In the lowering of heavy weights this is especially the case, for sometimes slight slips occur in the links of the chain, or the load has to be stopped suddenly in its descent. Hence we are accustomed in mechanical construction to introduce what is called the "factor of safety." Thus, in the present case, instead of making the tie just strong enough to bear the utmost load the crane is intended to raise, we make it ten times as strong: the factor of safety is then said to be 10. In a crane the factor of safety should not be less than 10. It is sometimes even more than this; but in other machines which are not exposed to the rough usage to which cranes are liable, the factor need not be so large.

Wrought iron, from its great tenacity, is admirably adapted for making the ties of cranes. A rod of iron one square inch in section will require a force of nearly twenty tons to tear it asunder. Hence we must make a crane on the proportion of Fig. 1 with a wrought-iron tie ten square inches in section, as it will then be able to withstand any strain less than 200 tons—that is, it will be ten times as strong as would be absolutely required for the bare purpose of sustaining the weight. In every case the tie, if made of wrought iron, should have a total section in no place less than half an inch for each ton of strain.

The jib AC has to withstand a thrust. In fact, it is a pillar, and the component of the load which it supports is tending to crush it. It must therefore be made of materials which are capable of resisting a crushing force. In ordinary cranes it is very often made of a piece of timber, which is very well adapted for resisting a crushing force. A bar of wrought iron, such as would make an admirable tie, would be quite unequal to withstand the crushing without being of great size and cost. Sometimes both jib and tie are cast in one piece of cast iron. This arrangement answers well for cranes which are used for raising a few tons, but would be quite unfit for the largest cranes, on account of the massiveness which would be necessary to give sufficient strength. By far the best arrangement for the jib of a large crane is a girder of riveted wrought iron; for by means of this arrangement the material is so disposed as to present a large amount of resistance to a force of crushing.

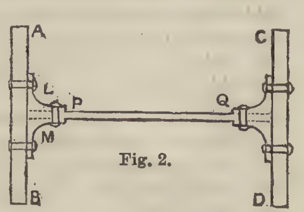


Fig. 2.

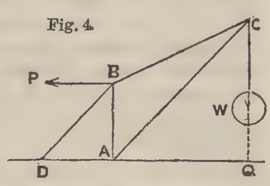
The form which a wrought-iron jib may have will be understood from the section shown in Fig. 2. AB, CD are iron plates, which are riveted together in lengths. A good plan of fastening these plates together is shown in Fig. 3, where the plates overlap, and are riveted together, the object of the arrangement being to have the united pieces just as strong at the joint as elsewhere. Two plates the whole length of the jib are thus prepared, and they are shown in section in AB, CD of Fig. 2. Now these plates being thin in proportion to their length, would not be stiff unless secured together. They are perhaps one inch thick by about ten inches wide, and as they may be fifteen feet long, they are in reality only strips or ribbons. They are then bound together by plates of iron, of which the section is shown at PQ. These plates of iron are attached to the plates at right angles by means of what are called angle-irons, shown at L and M. These angle-irons are riveted to both, and so the whole is bound into one piece. The process of riveting is admirably adapted for this purpose, as the rivet in cooling exerts a tremendous force in drawing the pieces together.

Fig. 3.

A jib made in this way is light, and at the same time extremely strong. In fact, it is hard to see how such a jib could be crushed unless the rivets were actually torn across; and they are made strong enough to prevent this from being likely to happen. The thrust which the jib has to support is generally at least three or four times as great as the load which the crane supports. This is evident from the fact that the three forces are proportional to the sides of the triangle ABC; so that these precautions are not unnecessary.

We have, then, examined briefly into the structure of the jib and the tie. We now come to consider the part AB (Fig. 1) by which they are supported. The post has another important duty to fulfil—it supplies the pivot about which the crane turns. This is often made of cast iron, and is firmly embedded in solid masonry. The post requires to be very stout, as there is a great strain upon it tending to snap it off at A. The magnitude of this strain may easily be understood when we remember the principle of moments, which has already been laid down in Lesson IX. in "Mechanics." If W be the magnitude of the load, and AQ (Fig. 4) be the length of the perpendicular from A in the direction of W, then $W \times AQ$ is the moment with which the weight tends to wrench off the post AB; but the moment $W \times AQ$ is equivalent to—

Fig. 4.



$$\frac{W \times AQ}{AB} \times AB;$$

and hence the force tending to break the post is equivalent to a force—

$$\frac{W \times AQ}{AB}$$

acting at a distance AB. This is in general larger than W.

If we suppose A B not to be firmly embedded in the ground, we must by some other means exert a force upon it sufficient to counteract the moment of the weight. There are two different ways in which this may be accomplished.

In a crane which is often used for quarrying and other rough purposes, and which is sometimes called a *guy crane*, there are two stays, one of which, B D, is shown in Fig. 4. These stays are attached at one end to the top of the post, while the other end is firmly secured into the ground. By this means the post is supported without being itself of great strength or embedded very deeply. The disadvantage of this form is that the crane takes up a great deal of room, and also that it is only able to turn round a part of an entire circle, as the jib comes in contact with the stays in the extreme positions.

Another method by which a crane-post can be supported is by having a counterpoise on the other side, which counteracts the effect of the load. This arrangement is particularly convenient for portable cranes, when it is impossible to secure the post in the ground, or even to be able to fasten the ends of the stays of a guy crane.

A very convenient portable crane on this principle is shown in Fig. 5. Here the boiler and fireplace of the engine which works the crane project behind, and their weight acts as a counterpoise to whatever load may be suspended from the hook W.

This crane is adapted to run upon a tramway, and is thus very convenient in all operations connected with the transport of heavy materials. The tie is in this case partly composed of a wrought-iron rod and partly of a chain, which passes through a pulley at D. The object of this arrangement is to enable the jib to be raised or lowered as the exigencies of the work may require. This chain is not to be confounded with the lifting chain, which will be presently considered. The jib, A B, in this crane is formed of timber. It will be seen that it is to some extent spindle-shaped. The reason of this is that the jib is more liable to break in the middle than at either end, so that by giving to it this form it is made of an equal strength throughout.

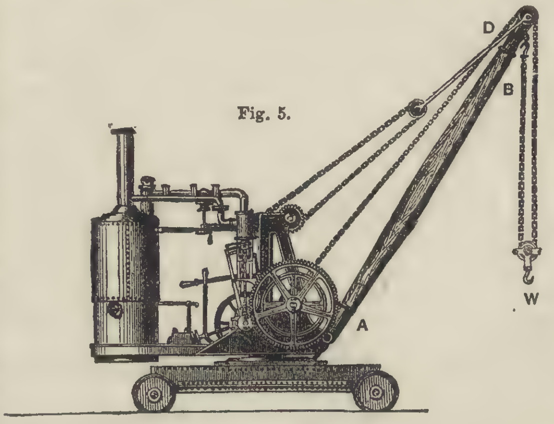


Fig. 5.

THE WHEELWORK.

The hoisting apparatus is entirely distinct from the framework which we have been considering. It consists of a barrel or drum, on which the chain is wound, and a train of wheels, through the intervention of which the barrel is turned by a handle. The nature of the train of wheels depends upon the load which the crane is intended to raise and the power which is employed.

In order to explain this, we shall take a simple case first. Suppose we have a pinion of 20 teeth mounted upon a shaft, and that this shaft is turned by a handle which moves in a circle of three feet in diameter. Now let this pinion turn a wheel of 200 teeth, and on the same shaft as the wheel let a drum one foot in diameter be secured. Now supposing this arrangement be applied to a crane, and that the chain pass over the pulley at the top of the jib, and have a weight suspended from it, what weight will one man turning the handle be able to raise?

The principle of virtual velocities will determine this. We must first ascertain the space through which the power of the man must be applied in order to raise the load a given distance. When the barrel has made one revolution, $\frac{22}{7} \times 1 = \frac{22}{7}$ feet of chain will be pulled in. But when the barrel has made one revolution, the wheel of 200 teeth must also have made one revolution. But the pinion which gears into this wheel must have made ten revolutions, because the wheel has ten times the number of teeth in the pinion. The handle must therefore have been turned round ten times. Now the handle describes a circle three feet in diameter, and therefore the distance through which the power of the man must be exerted is $3 \times \frac{22}{7}$ for one revolution; and therefore $30 \times \frac{22}{7}$ for ten revolutions.

Thus the virtual velocities of the power and the load are $\frac{22}{7}$ and $30 \times \frac{22}{7}$. But by the principle of virtual velocities already referred to in the "Lessons in Mechanics," the mechanical efficiency of the machine is the ratio of the virtual velocities, that is—

$$\frac{30 \times \frac{22}{7}}{\frac{22}{7}} = 30.$$

Hence the efficiency of this crane is thirtyfold—that is, for example, if a man exerted a pressure of 40 lb. on the extremity of the winch, he would be able to raise $40 \times 30 = 1{,}200$ lb.; and therefore two men at such a crane could raise a ton with ease.

But we often find in cranes more than a single wheel and pinion. There are sometimes two wheels and two pinions in powerful cranes; but in all cases the mechanical efficiency may be found by the following rule:—

Multiply the diameter of the circle described by the handle into the product of the number of teeth in all the wheels.

Multiply the diameter of the barrel by the number of teeth in all the pinions.

The former of these products divided by the latter gives the mechanical efficiency of the apparatus.

Thus, for example, suppose a crane in which the handle and barrel were the same as in the last example, but that on the shaft turned by the handle was a pinion of 12 teeth, which worked into a wheel of 180 teeth, and that on the shaft carrying the latter wheel is the pinion of 20 teeth working into the wheel of 200 teeth which carries the barrel.

Now the product of the diameter of the circle described by the handle with the numbers of teeth in the two wheels is—

$$3 \times 180 \times 200;$$

and the product of the diameter of the barrel and the numbers of teeth in the pinions is—

$$1 \times 12 \times 20.$$

Hence the mechanical efficiency is—

$$\frac{3 \times 180 \times 200}{1 \times 12 \times 20} = 450.$$

In a crane fitted with hoisting machinery of this kind a man exerting a power of 40 lb. could raise a load of—

$$450 \times 40 = 18{,}000 \text{ lb.}$$

The rule which we have given is very easily proved, and the reader will find it a useful exercise to deduce it from the principles laid down in Lesson IX. in "Mechanics."

In the crane represented in Fig. 5, the mechanical efficiency is doubled by the movable pulley from which the load is suspended. Supposing this crane, then, to have the train of wheels which we have described, its mechanical efficiency would be 900.

It will be noticed that we have taken no account of the effect of friction when speaking of the crane. The reason of this is that when the machinery is in proper order the amount of friction is small. We can see at once in any crane that at all events less than half the power is lost by friction, because the weight will go down by the run if allowed to do so. In fact, this has often been the cause of very serious accidents; but we have already laid down that in no machine where more than half the power is lost by friction is it possible for the load to overrun. Hence the loss in the crane is less than a half. Practically it will not in a well-constructed crane be more than a fourth or a fifth.

THE STEAM-ENGINE.—III.

By J. M. Wigner, B.A.

FEED APPARATUS—STAND-PIPE FOR LOW-PRESSURE BOILERS —"GIFFARD'S INJECTOR"—"BUCKET BOILER FEED"— SAFETY-VALVES—PRESSURE GAUGE.

The first point which demands our attention in the present paper is the manner in which fresh supplies of water are from time to time introduced into the boiler, to take the place of that which has been converted into steam. The importance of attending very carefully to this will be seen from our last paper, and from the fact, that in a large proportion of boiler explosions the cause has been found to be an insufficient supply of water.

Much attention has therefore been directed to the construction of self-acting feed arrangements, which shall act quite independently of the engineer, and thus obviate the risk of accident by neglect on his part. There is some difficulty in accomplishing this, mainly arising from the fact, that the steam inside the boiler is at a high pressure, and that the water has therefore to be forced in, and that, too, without allowing any escape of the steam.

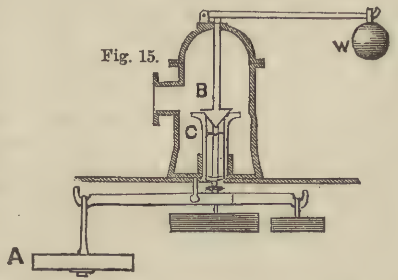
If cold water be employed to feed the boiler, the temperature of the whole is considerably reduced, and an increased expenditure of fuel is thereby rendered necessary. This may easily be, to a great extent, avoided, for the steam, when it has accomplished its work and escapes from the cylinders, is still at a high temperature, and may therefore be advantageously used to warm the feed. In this way a considerable amount of heat which would otherwise be wasted is utilised. Arrangements are usually made by which the heated water from the condenser, or other parts, flows into a hot-well, from whence the boiler is fed.

In condensing or low-pressure engines, the waste steam is condensed by means of a jet of cold water in the condenser, and in some instances special arrangements are made, by which a portion of this water leaves the condenser at a temperature very little below the boiling-point.

The construction of the feed apparatus varies, according as the engine is a low-pressure or a high-pressure one. In the former class, the pressure of the steam in the boiler does not usually exceed that of the atmosphere by more than about six or eight pounds to the square inch, and water is then commonly supplied by means of a vertical stand-pipe with a small cistern at the upper end, as shown in Fig. 12. H is the stand-pipe, which passes nearly to the bottom of the boiler, and is of such a length, that the ordinary pressure of the steam will keep the water nearly up to the top of it. At the top is a small cistern, opening into H by means of a valve attached to the rod D.

This rod is jointed to the lever B C, and the valve is usually kept closed by the weight C. Attached to the other end of the lever is a rod, I, which passes through a stuffing-box, G, and is fastened to a float, A.

Fig. 15.



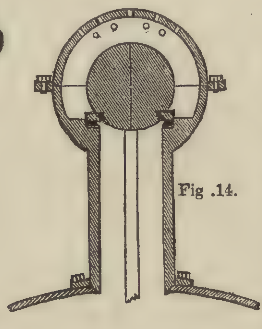


Fig .14.

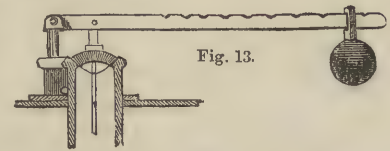


Fig. 13.

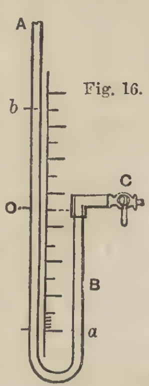


Fig. 16.

Fig. 17.

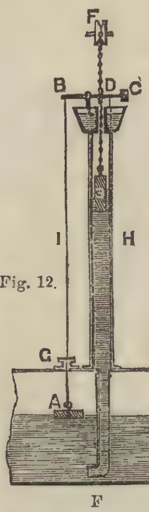


Fig. 12.

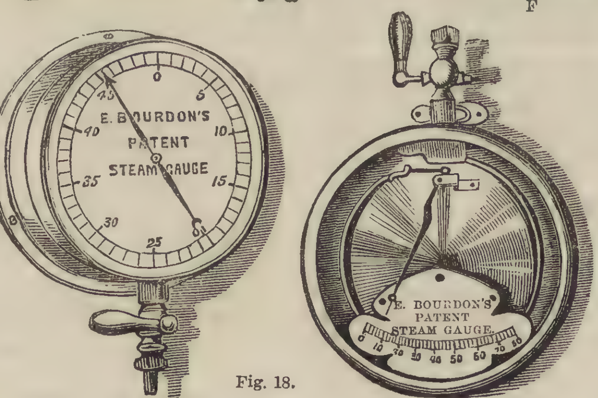


Fig. 18.

When the level of the water in the boiler falls, the float A sinks likewise, and in so doing opens the valve and allows water to pass from the cistern into the boiler till the level is restored. The weight C then closes the valve again. When the apparatus is working properly, the float keeps the valve a little way open, so that a small stream of water enters at just the rate at which it is evaporated, and thus the level does not fluctuate to any perceptible degree.

In the tube H is seen a float E, which is connected with a damper in the flues in such a way, that when the pressure of the steam increases, and the level of the water in H consequently rises, this float rises likewise, and in so doing lowers a damper which checks the draught till the pressure of the steam again diminishes. A double purpose is in this manner served by the stand-pipe: it regulates the feed, and also the draught.

There is one drawback to the use of these self-acting feed arrangements, and that is, the fear lest the valve should stick in its seat, or the rod connected with the float should become fixed in the stuffing-box, and thus cause the apparatus to cease to act. The engineer might then go on supposing that all was right, and omit to look at his gauge-glass till the boiler was seriously injured. This objection of course applies to all self-acting arrangements; but, with ordinary care, it is not a serious one. The important point is for the engineer not to trust solely to the apparatus, but frequently to consult the gauge as well, and then all danger will be avoided.

This apparatus is clearly inapplicable to high-pressure boilers, since the pressure in them is seldom less than thirty or forty pounds to the square inch, and often very much greater. A stand-pipe would therefore have to be carried to a great height, and be altogether impracticable. For these boilers, then, a different plan has to be adopted, and the most usual arrangement is to have a small force-pump to drive the water from the hot-well into the boiler. This pump can be thrown out of gear at pleasure, and a cock is usually placed in its suction-pipe, so as to limit its action when required. Sometimes this force-

pump is connected with the engine and driven by it; in other cases it is altogether separate, being worked by a small engine of its own. This latter plan is generally adopted in cases where several different engines are driven from one boiler or one set of boilers, the advantage being that the pump can be set in action even though the engines are at rest, and it is also more under control.

The engineer then observes the gauge-glass, and regulates the action of this pump accordingly. It is very desirable, however, so to regulate it that the level of the water varies as little as possible; for frequent fluctuations—even though not sufficiently extensive to endanger the boiler—render the generation of steam less uniform, and to a certain extent impair it.

A very ingenious apparatus, known as "Giffard's Injector," is now frequently employed as the means of injecting water into high-pressure boilers. The action of this is somewhat strange, since the water is forced into the boiler by the pressure of the steam on the surface of the water in the instrument, and this pressure is clearly less than that of the steam in the boiler. One great advantage of this instrument is the absence of all valves, with the exception of one placed as a check where it is connected with the boiler, and serving to prevent the escape of water when the instrument is not in action. It cannot, however, be employed when the temperature of the feed-water is much above 120°, as a part of its efficacy appears to arise from the condensation of the steam. This is a drawback to its more general adoption, since it is always very desirable to have the feed as hot as possible.

A very ingenious self-acting feed apparatus for high-pressure boilers, known as the "Patent Bucket Boiler Feed," is now extensively adopted. The construction of this is rather complicated, so that it is difficult to explain it without a model; the principle on which it acts is, however, simple. The feed-water flows into a tumbling bucket mounted on one end of a lever, the other end of which carries a counterpoise. When full, this bucket upsets into a small cistern, whence the water may flow through a valve into the feed-pipe, which passes nearly to the bottom of the cylinder, and is closed at its upper end. When the bucket is *nearly* full, it overbalances the counter-weight and turns the lever a little way; in so doing it opens a valve, which allows the steam from a special steam-pipe to enter the top of the feed-pipe, and drive the water from it into the boiler. The mouth of the steam-pipe in the boiler is just at the level at which the water ought to stand; if it rises above this, no steam can escape, and consequently no more water is driven into the boiler till the proper level is restored. As soon as the bucket is quite full, it upsets and empties itself. The counterpoise then restores the lever to its original position, and closes the steam-valve again. A waste-pipe carries off the excess of water from the cistern; and the supply should be so arranged that it may slightly exceed the consumption in the boiler.

In order to guard against the risk of explosion, should the level of the water at any time by accident or neglect fall so low as to admit of the tubes or plates being unduly heated, "fusible plugs" are sometimes employed. A short nozzle is attached to the boiler just below the lowest level at which the water may safely stand. On this there is screwed a cap, the centre portion of which is composed of an alloy that melts at a temperature not very much exceeding the boiling-point. So long as this plug is kept covered with water, it remains firm, the heat being carried away from it by the water; but should the level fall so low as to expose it, the centre at once melts, and allows the steam and part of the water to escape into the flues and furnace, damping or extinguishing the fire and at the same time removing the undue pressure. Should this happen, the boiler must be left to cool sufficiently to admit of a fresh cap being screwed on in place of the used one.

In practice it is found that these plugs cannot always be relied on, as after the lapse of a little time they become incrusted or injured by the heat, and thus lose somewhat of their efficacy. The only safe plan is to change the cap at frequent intervals. Plates of fusible metal have also been proposed to be inserted in different parts of the boiler with a similar purpose, but they have not been adopted.

The next appendage to the boiler that we must notice is a very important one—the safety-valve. Steam is frequently generated more rapidly than it is consumed in the engine, or sometimes the engine is stopped for a short time, and thus the steam is allowed to accumulate. The natural consequence is that the pressure inside the boiler goes on gradually increasing, and in a little time it would become so great as to cause it to explode with fearful violence. To guard against this risk, some contrivance is needed which shall allow the steam to escape before its pressure becomes so great as to be dangerous, but which at the same time shall, under ordinary pressure, prevent any loss. The safety-valve is intended to accomplish this object.

The ordinary form of valve is represented in Fig. 13. It is placed in some convenient portion of the surface of the boiler. The movable portion is usually fixed on a spindle, so that it may be kept horizontal, and always fall back exactly to its seat. This valve is kept closed by means of a lever, fitted either with a sliding weight or an adjusting spring, so that the pressure can at pleasure be moderated to any required extent. It is usually set so that the valve opens as soon as the pressure is a little above that at which the engine is to be worked.

One serious drawback to the use of the conical valve is its liability to become corroded and fixed into its socket, so that it ceases to act. More than one explosion has, on inquiry, been found to result from this cause. To guard against this, it is well from time to time to raise the weight, and thus allow the valve to open by the pressure of the steam. Spindles, and other arrangements for guiding the valve, are also very liable to become corroded, and thus prevent its due action. A very ingenious arrangement has been planned to obviate this difficulty, and ensure the accurate fitting of the safety-valve: this is represented in Fig. 14. The valve consists of a spherical ball with a rod passing through its centre. This ball exactly fits in a circular seat; but the chief peculiarity consists in an arrangement by which the ball is kept continually in motion, so that the surfaces in contact do not remain stationary, and therefore cannot corrode. Inside the boiler there is always a certain amount of movement in the water caused by the ebullition: a sheet of iron is therefore attached to the rod passing through the ball, and allowed to dip down some way into the water. The ebullition makes this oscillate a little, and by this means the motion of the ball in its bearings is maintained. In this way a very perfect fit between the valve and its seat is secured. The weight on this valve consists of the ball and iron attached to it, and cannot, therefore, easily be altered.

It is customary to have two safety-valves to every boiler: the one is usually either locked, or so arranged that it cannot be altered by the engineer, and this is adjusted so as to open at the highest pressure the boiler can safely bear; the other is adjusted according to the pressure of steam it is intended to employ. A boiler should always, before being used, be tested by hydraulic pressure, to ensure its being sufficiently strong. This is usually done by filling it completely with water, all openings being closed. Water is then forced in through a small aperture by means of a force-pump, which records the exact pressure in pounds per square inch. A boiler will, however, sometimes be found to leak even after having been proved in this way; since when heat is applied to it, the iron expands and some of the joints become loosened.

A form of safety-valve, now very generally employed, is known as "Hopkinson's Double Safety-valve," and is shown in Fig. 15. The special advantage of this is that it guards against explosion, either from excess of pressure or deficiency of water.

The valve is placed inside a dome, which protects it from injury; a large opening is, however, left at one side for the steam to escape. The part B has a curved surface, and accurately fits on the top of the pipe C, which communicates directly with the boiler. The weight W slides along the lever, and in this way the pressure can be adjusted to the required amount. Thus far this valve resembles that in ordinary use; the peculiarity of it consists in the internal lever and weights. The float A is so adjusted, that when the water in the boiler is at its proper level, the lever from which it hangs is horizontal, and the valve is closed. If, however, the level falls, this float sinks likewise, and in so doing raises the valve by means of the spindle under it, and thus allows the steam to escape. In some instances the steam, as it blows off from the safety-valve, is made to sound a whistle, and thus call the immediate attention of the man in charge of the engine.

There have been many other variations in the forms proposed for safety-valves, for, owing to their great importance, much attention has been directed to the discovery of the best and

safest construction; but space will not allow us here to explain the details of these.

When the lever of the safety-valve is properly graduated, the weight can be so adjusted as to allow the valve to open at any given pressure, and we at once ascertain the fact of this pressure being attained by the escape of the steam. The heat in the furnace ought, however, to be so regulated by means of dampers in the flues, that the steam shall be kept up to the required pressure, but not allowed to exceed it, since all that escapes by the safety-valve is in reality a loss of so much heat. In order to do this, we need some mode of indicating at any moment the exact pressure which the steam exerts, and this we learn by means of the "pressure-gauge."

Various forms have been given to this instrument; the simplest is that known as the mercurial gauge for low-pressure boilers (Fig. 16). It consists of a tube bent in the shape of a syphon, the longer end, A, being open, and of such a length that the pressure of the steam will not force the mercury out of it. A stopcock, C, is placed at the other end, and beyond it a screw is cut, by means of which the gauge is attached to the boiler. The bend of the tube is now filled with mercury till it stands in both limbs at the level, O; a small air-hole, closed by a screw, is often placed near C to aid in the filling. As soon, now, as the cock C is opened, the mercury in the limb B will be pressed upon by the force of the steam in the boiler, while the surface of the mercury in the other limb will be acted upon by the pressure of the air. The difference in level in the two limbs will at once show the difference in pressure. If the force of the steam be such as to depress the mercury in B to *a*, it will, of course, rise as much above O in A, and will stand at *b*. The difference in level between *a* and *b* will thus show the amount by which the pressure in the boiler exceeds that of the air, which may be taken at 15 pounds per square inch. A graduated scale is usually placed between the two limbs, by means of which the difference may easily be read off. Most commonly the tube is made of iron, as glass is very liable to be broken; a float is then placed in A, and a counterpoise is connected to it by a string passing over a pulley at the top. This counterpoise serves as an indicator, and marks the pressure on the scale.

As the difference in the level of the mercury in the two limbs amounts to about two inches for each pound of pressure, it is clear that this kind of gauge cannot well be employed with high-pressure boilers without being made very inconveniently large. A totally different form is therefore made use of, the construction of which will be easily seen by reference to Fig. 17.

A tube of strong glass, closed at the upper end, is made to dip into a closed vessel containing mercury, on the surface of which the steam presses. As this pressure increases, the air in the tube is compressed, and the mercury rises.

A specially graduated scale is placed at the side of the glass, which shows exactly the extent to which the air is compressed. If the mercury stands half-way up the tube, the air occupies just half its ordinary space; the pressure of the steam, therefore, is twice as great as that of the air—that is, it amounts to 30 pounds to the square inch. If the air is compressed to one-third of its bulk, the pressure is 45 pounds, and so on.

Mercurial pressure-gauges have, however, almost entirely given place to those known as "Bourdon's." In this there is a dial-plate, with a hand on it pointing to the pressure, as seen in Fig. 18. The steam acts upon a spring of a peculiar construction, somewhat on the plan of that used in some aneroid barometers; and, owing to their greater convenience, these gauges are now almost universally adopted.

COLOUR.—IV.

By Professor CHURCH, Royal Agricultural College, Cirencester.

MAXWELL'S THEORY OF PRIMARY COLOURS.

IN continuation of our remarks upon the various theories which have been propounded as to the true primary colours, we may now refer to the conclusions of Professor Clerk Maxwell. According to this observer, the three primary colours are scarlet, green, and blue. By the combination of these colours he considers that all others may be formed; but at the same time he admits that the other colours of the spectrum are due to simple or undecomposible rays, though they excite the same sensations as those of certain mixtures of rays. A bluish-green ray, for example, though not compounded of blue and green rays, produces a sensation which may be regarded as compounded of those sensations which are produced by blue and green. In their selection of the three most important colours of the spectrum, in their divergence from the ordinary theory as to the primary colours, and in their views as to complementary colours, Helmholtz and Maxwell agree to a considerable extent: it is as to the possibility of forming from three colours all the others that they differ—Maxwell affirming this, and Helmholtz denying it. A few words as to the primary, secondary, and complementary colours admitted by Maxwell may now be given. In order to observe these colours satisfactorily, the following contrivance should be adopted:—Two slips of pure white unglazed paper should be laid upon a piece of black velvet, after the manner represented in Fig. 9. If this diagram be thus copied in paper and velvet on a large scale, and viewed from a distance, by means of a prism having its refracting edge turned away from the spectator, the colours will be seen as indicated in the figure. These colours are the two complementaries. By varying the shape of the black and white spaces, new and instructive effects may be developed, which we have not space to describe particularly. One of these variations is made by placing a narrow white strip across the middle of a long black band, and a similar narrow black strip across a contiguous long white band, and continuous with the white strip.

Fig. 9.

According to the deductions of Maxwell, the most effective three primary colours for the purpose of compounding the largest numbers of other colours have the following wave-lengths in millionths of an inch, and the following positions in the spectrum of the sun (Fig. 10):—

Names of Primaries.	*Wave-lengths.*	*Positions.*
Pure red or scarlet . .	2,328	$\frac{1}{3}$ from line C to D.
Pure green	1,914	$\frac{1}{4}$ from line E to F.
Pure blue	1,717	$\frac{1}{2}$ from line F to G.

The secondary colours complementary to these primaries are—

Sea-green,	*complementary to*	Red.
Almond-blossom	"	Green.
Yellow	"	Blue.

Some authors call the colour we have here named "almond-blossom" pink, others peach-blossom. It contains less blue than does violet, which is not its true complementary. The best representation of the particular colour here meant is to be obtained by burning the gas known to chemists as cyanogen—easily obtained by heating a little mercuric cyanide in a short test-tube fitted with a fine glass jet to serve as a burner.

These three secondary colours, in order to be truly complementary to their several primaries, must not only be of the right quality and purity, but must be of the right intensity or brightness. So the sea-green named above must have the added brightness of its two components, blue and green; the almond-blossom must have the added brightness of its two components, red and blue; and the yellow must have the added brightness of its components, red and green. Of course these statements refer only to Maxwell's theory of the colours of light. In the case of pigments we shall have frequent occasion further on to repeat what we have indeed often stated before—that the complex nature of the coloured rays they generally reflect does not permit these simple relations of colours to each other to hold good. In concluding our brief outline of some of the chief features of the new theory of colour, we may draw our readers' attention to the following diagrams (Figs. 11 and 12) by means of which, when filled in with the colours named, they can represent for themselves the primary and secondary colours of Maxwell's theory.

In these diagrams the following abbreviations are used:—

I. *Primary Colour.*—R, Red; G, Green; B, Blue.
II. *Secondary Colour.*—S G, Sea-green; A, Almond-blossom; Y, Yellow.

When the diagrams are filled in with the purest pigments attainable, then Fig. 11 should show the effect of taking away the three primary colours from white, leaving three overlapping circles of secondary colours where only one colour is removed;

leaving three-sided spaces of primary colours where two colours are removed; and leaving also a similar space of black or darkness in the centre, where all three primaries are equally removed. The exact converse of this effect is shown in Fig. 12, where the primary colours are supposed to be represented in equal strength upon a black ground. They form, by the overlapping of two of the three circles or discs containing them, three spaces of the secondary colours, and where all three circles overlap or coincide, a central space of white. Coloured lights are, of course, alone competent to produce secondary colours brighter or more luminous than their constituent primaries. A similar but thoroughly false imitation of this effect is produced by mixing white with the secondary colours used in preparing the above diagrams.

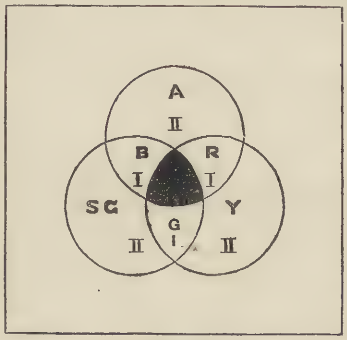


Fig. 11.

The more commonly received theory of the primary colours must now be described. It is still adopted in all the manuals of design and colour as applied to the decorative and fine arts; indeed, the authors of such books seem to be ignorant of the existence of the more correct views which have just been described. One great advantage is possessed, we readily admit, by the old theory—it works far better with actual pigments than does the new one. It breaks down more or less completely when tested, by the means we have already mentioned, with coloured rays of light. Concerned as we usually are with coloured materials and not with coloured rays, we shall describe the old theory at some length, particularly as it affords an easy means of studying the mixed colours which pigments afford.

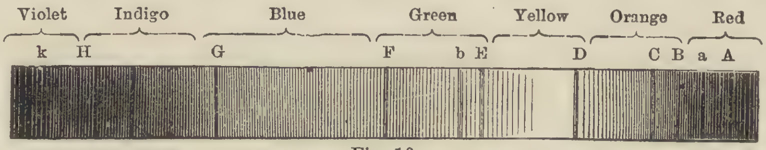


Fig. 10.

In our coloured diagram* we have arranged the most important colours in a six-pointed star made of twelve equilateral triangles. The whole figure being regarded as consisting of two intersecting triangles, the three primary colours will be found in the angles of one of these, the three secondary colours in the angles of the other, and the more mixed hues in the area where the two triangles coincide or overlap. However, before showing how the compound colours may be supposed to originate from the admixture of simple ones, it will be necessary to define the meanings of a few words which we shall have frequent occasion to employ.

Fig. 12.

Tones, often called shades, signify colours mixed with varying proportions of white or black. In mixing a colour with white we weaken or reduce its tone, but by the addition of black a colour has its tone broken or darkened, not deepened. Red mixed with white in increasing proportions gives weaker and weaker tones of red; red mixed with black in increasing proportions gives duller and duller tones of red; while red mixed in a similar manner with both white and black—that is, grey—gives a series of tones of red which are at the same time duller and weaker than the original colour.

A *scale* is a regular series of such tones as those just described. Every colour admits of three scales:—

1. The reduced scale—that is, the normal colour mixed with white, thus forming *tints*.

2. The darkened scale—that is, the normal colour mixed with black, thus forming *shades*.

3. The dulled scale—that is, the normal colour mixed with both white and black, or, in one word, with grey.

Primary or elementary colours are usually regarded as three in number, and are assumed to be capable of yielding by combination all other colours. They are commonly assumed to be yellow, red, and blue.

Secondary colours are mixtures of two primaries in equivalent proportions. Orange, green, and violet are the three secondary colours. We say equivalent, not equal proportions; for it will be found that equal quantities of yellow and red lights, or of the purest yellow and red pigments attainable, will not produce the normal orange. In making, therefore, such a secondary colour as orange, we have to judge by the eye what quantities of its primary constituents will produce a colour equally removed from yellow on the one hand, and from red on the other.

Tertiary colours are mixtures of the three primary colours in certain proportions, which will be noticed presently. All tertiary colours are dull, owing to the following fact. All pigments representing the three primary colours produce, when mixed together in equivalents, not whiteness, but greyness or blackness. In tertiary colours, therefore, the equivalents of yellow, red, and blue which are present, unite to neutralise one another, and so to form grey; while it is only the unneutralised residue of the one or two colours that are in excess which gives a special character to the final result. The neutral grey of the tertiaries, as thus produced, dulls all their tones, and distinguishes them at once from the primary colours, and from all combinations of two primaries. Indeed, the six normal tertiary colours are nothing more than the *dulled* tones of the three primary and the three secondary colours.

Hues include all tertiary colours, and all those colours in which the primaries are mixed in other proportions than are requisite to form the secondary colours. Yellowish-orange and bluish-green are secondary hues; reddish-grey and violet-grey are tertiary hues.

With these definitions of terms before us, the consideration of the chief colours, of the quality and optical composition of coloured materials, and of the pigments in actual use, may be commenced.

THE PRIMARY COLOURS.—*Yellow.*—The most luminous of all colours is the pure yellow. It occupies a very narrow space in the solar spectrum, but is distinctly the brightest part of it. Most yellow pigments and coloured materials reflect or transmit much orange and red light, as well as yellow. Chrome yellow is an example of this fact. Some transparent yellows on a white surface, such as gamboge, allow the transmission of, or reflect much white light, in addition to the yellow rays which characterise them. They are in reality reduced yellows—yellow, that is, mixed with white. Yellows occasionally verge upon green, especially in their lighter tints. This effect is partly due to their reflection of some green rays in place of the red which they usually emit, and partly to the result upon the eye of contrasting the lighter or reduced tones of yellow with the darker tones which verge upon orange and red. An orange or even a red tint is often perceived in yellow pigments when they become dry, though they may have appeared of a nearly pure yellow when wet. Fibres of wool, silk, cotton, etc., dyed yellow, exhibit the same appearances, as to the optical constituents of the colours they reflect, as do other white surfaces of paper, canvas, and porcelain, upon which opaque or transparent pigments have been spread. In all cases varying proportions of white light are reflected; while of the light which is decom-

* The coloured diagram was published with Part I. of THE TECHNICAL EDUCATOR.

posed by the coloured surfaces, different but considerable amounts of violet, indigo, blue, and, in a measure, green, are quenched or absorbed. The remaining rays produce the colour effect of the object, and will, of course, consist mainly, but not entirely, of yellow light. With stained glass and other transparent materials, such as coloured gelatine and coloured liquids, similar groups of violet and blue rays are on the one hand absorbed, while on the other hand the less refrangible colours are transmitted.

Red.—The second primary colour in point of vividness is red. It is less luminous than yellow, but warmer and more retiring. All our ordinary red colours contain orange and yellow, or else blue and violet. A stick of sealing-wax examined by a prism is found to reflect all the rays up to the line D in the yellow—that is, the colour which it presents is made up of much orange and a little yellow in addition to the true red. The fugitive paint known as geranium colour is a purer red than that just named, the vermilion of sealing-wax, but it is not free from a tint of orange. Carmine and crimson lake, with other similar pigments, reflect to the eye a trace of the blue and violet, as well as nearly all the red, and some of the orange rays of the light which falls upon them. The best idea of pure redness may be got from the bright and broad red band in the spectrum of a burning lithium salt. Red glass, at least that kind of red glass which is coloured by copper suboxide, does not transmit unmixed red rays, but many orange rays as well.

Blue.—The third and least vivid of the primary colours is blue. It is also the most retiring and cool. We cannot point to any tolerably pure blue pigment. Beautiful as ultramarine undoubtedly is, its spectrum reveals the existence of several colours besides blue. Yet it would be hardly fair on this account to regard this or any other colour as impure. If the various coloured rays which a pigment reflects to the eye impart the sensation of blueness, it is enough. They may contain red, violet, and other constituents, but the resultant effect of the combination may be a blue indistinguishable in purity from the normal blue of the solar spectrum. A difficulty does, however, arise when such pigments as those above referred to are illuminated by artificial light, or are mixed with others to form secondary and tertiary colours; the anticipated result being occasionally very far from being realised. Cobalt-blue reflects much green and violet light, as well as blue, and in fact shows a very remarkable combination of colours when its spectrum is examined. On mixing it with carmine, to form a violet hue, the green constituent in its light interferes with the purity of the resulting colour, which is much greyer than one would have expected. By lamp-light cobalt-blue appears violet. Prussian-blue and indigo absorb most of the red, orange, and yellow rays, but emit a very large part of the green, blue, and indigo. A crystal of blue vitriol (copper sulphate) cuts off all the red, orange, and yellow rays, together with the green rays up to line E, and transmits the remainder.

The secondary and tertiary colours remain for discussion in our next lesson.

SEATS OF INDUSTRY.—IV.

MANCHESTER AND ITS SUBURBS: THEIR CHIEF INDUSTRY.

By H. R. Fox Bourne.

Manchester has an antiquarian history, extending over nearly twenty centuries, and a commercial history, the authentic records of which hardly cover five hundred years. It ranks however, with the oldest English towns that attained importance by their manufacture of clothing and other textile goods.

Its first staple manufacture was not cotton but wool. When, in 1331, a few of those industrious Flemish emigrants who instructed the English in better ways of turning sheep's wool into cloth settled in Manchester, they gave new life to a trade that for some time previously had been feebly carried on. Two centuries later, one of the three most famous clothiers in England was Martin Brian, or Byrom, of Manchester; and at that time, in 1538, the town was spoken of by Leland as "the fairest, best builded, quickest, and most populous town of all Lancashire."

Linen manufacture, as well as woollen manufacture, had a share in making what is now the greatest of all the great cotton towns. "The town of Manchester," it was written in 1542, "is and hath of long time been inhabited, and the inhabitants of the said town have come into riches and wealthy livings, and have kept and set many artificers and poor folks to work within it; and by reason of the great occupying, good order, straight and true dealing of the inhabitants, many strangers, as well of Ireland as of other places, have resorted to the said town with linen yarn, wool, and necessary wares for making of cloths, and have used to credit and trust the poor inhabitants, which had not ready money to pay in hand, unto such time as the said debtors with their industry, labour, and pains, might make cloths of the wools, yarns, and other necessary wares, and sell the same, to content and pay their creditors; wherein hath consisted much of the common wealth of the town." That account of the help given to poor Manchester weavers by rich Irish merchants furnishes a curious illustration of the relative position of Irish and English which has so strangely altered during the last three centuries.

It is not necessary to note in detail the stages of the progress of Manchester during those three centuries. It grew steadily by help of wool and linen, although the progress was slow indeed in comparison with that of the past century, in which cotton has been the staple. In 1757, Manchester and Salford, then quite a distinct town, had between them hardly 20,000 inhabitants. In 1801 their population was 84,000, and in 1861 it was 460,000. The real Manchester, however, is very much more than the Manchester on the Irwell with its half a million inhabitants. Thirty or more important towns in southern Lancashire and western Yorkshire, and in the adjoining counties of Derbyshire and Cheshire, each with its own group of suburbs and outlying villages, constitute a vast network of cotton factories, with Manchester for the head and centre of the whole.

The development of the Lancashire cotton trade furnishes one of the most remarkable episodes in commercial history. It had a slender existence more than two centuries ago. "They buy cotton wool in London that comes first from Cyprus and Smyrna," it was said in 1641 of the Manchester manufacturers, "and at home work the same and perfect it into fustians, dimities, and other such stuffs, and then return it to London, where the same is vended and sold, and not seldom sent into foreign parts." While all the cotton wool that reached England came from the Levant, the supply was so small that no prejudice was excited by its use. As soon, however, as the East India Company began to bring home larger quantities, which were worked up both in the Manchester districts and elsewhere in England, the dealers in woollen goods began to fear that their own trade would be interfered with; and accordingly, using all their influence in Parliament, they obtained the passing of a series of laws, by which such heavy taxes were laid on cotton manufactures that for a time they were virtually prohibited. In London, and along the Thames, where Huguenot settlers had planted the trade, it was nearly stamped out. In Manchester it was carried on with difficulty until 1774, when the foolish laws were rescinded. The trade, thus relieved, had a little while before begun to be quickened by the arrival of cotton wool from the West Indies, and the American colonies which have now become part of the United States. The trade in England encouraged these new importations. The invention of new machines for spinning and weaving further encouraged them; and these causes, influencing and being influenced by the favour shown by the people for the new and cheap material for clothing, caused a marvellous extension of the trade. In 1768 the cotton goods manufactured in the whole of Great Britain were worth less than £200,000. By 1788 the trade had been more than doubled, and it was then large enough to give employment in spinning and weaving to 159,000 men, 90,000 women, and 101,000 children. Of 142 water-mills used in these manufactures, 41 were in Lancashire, 22 in Derbyshire, and 8 in Cheshire; that is, just half were in the district of which Manchester was the centre. In 1835 the number of factories in the Manchester district amounted to over a thousand, and the hands employed in them, and in connection with them, cannot have been far short of a million. The trade has more than trebled during the last generation. Manchester alone contains more than 200 factories, and in its far-reaching suburbs, from Preston to Macclesfield, and from Warrington to Rochdale, there are more than ten times as many. In 1860, said Mr. Bazley, "the number of spindles employed was about 32,000,000, and the number of looms employed would be about 340,000. The paid investments, including the value of land and the right of water, amounted to not less than £60,000,000, to which must be added a working

capital of £20,000,000. Add to these again the value of merchants' and tradesmen's stocks at home and abroad, the value of raw cotton and subsidiary materials, and of bankers' capital, and the grand total of capital employed in the trade will not be less than £200,000,000." No other single trade is so vast in its dimensions, or so important in its influences on society as the cotton manufacture, which has Manchester for its centre.

All the circumstances of the trade have grown in proportion. Dr. Aiken, the old historian of the town, tells how, a century and a half ago, "an eminent manufacturer used to be in his warehouse before six in the morning, accompanied by his children and apprentices. At noon they all came into breakfast, which consisted of one large dish of water pottage, made of oatmeal, water, and a little salt, boiled thick, and poured into a dish; at the side was a pan or basin of milk, and the master and apprentices, each with a wooden spoon in his hand, without loss of time, dipped into the same dish, and thence into the milk-pan; and as soon as it was finished they all returned to their work." Those simple ways gradually gave place to more refinement and conventionality; but the accounts of old Robert Peel's early life, and of his commencement of calico printing, show a state of things almost as primitive. As Peel grew rich, and became the master of a score of mighty factories, giving work to 1,500 hands, so Manchester and its suburbs have grown. The old modes of labour, by which each cottage was generally a distinct workshop, and each workman his own master, have been displaced by arrangements which necessitate the presence of hundreds of workpeople under one roof to manage the complicated machinery now in vogue, and that machinery enables each hand to get through fifty or a hundred times as much work as the old tools rendered possible.

The numerous stages of cotton manufacture may be grouped under three divisions. The first comprises all the processes by which the great lumps of cotton wool brought from the United States and other parts, through Liverpool, to Manchester and its suburbs, are reduced to yarn fit for weaving. The cotton is, in the first instance, *cleaned* by removing all impurities, and separating the coarser from the finer qualities. Then it is *carded*, that is, all tufts and knots are removed, and the fabric is laid out in a fleecy ribbon-like web. Next it is *drawn*, so that the ribbons may be all of the same quality and texture, and the filaments all exactly parallel. After that it is *roved*, a process by which each ribbon is greatly attenuated, and at the same time slightly twisted, so as to give it more strength and consistency. *Fine roving* follows, being, as the term implies, a more delicate repetition of the former operation. The sixth process is the *spinning*, which completes the production of the yarn, except that it has to be wound and packed before it is ready to be passed over to the weaving-shops. All these processes hang together, and are generally carried on in one department. The weaving is often conducted in the same factory, but it need not be so, and many cotton colonies are for spinning and nothing more. The weaving stage consists of fewer processes, but these are more complicated, some of the most wonderful exploits of modern invention being concerned in the adaptation to vast machinery of the same principles which guided the hands of the old weavers and websters during the thousands of years that preceded the introduction of machinery. We hope to be able to describe these in a future number, as well as the interesting processes of the third stage, in which the cotton wool, now converted into cloth, is dyed, printed, or otherwise finished, so that it may go out for sale as muslin or calico, wearing apparel, curtains, counterpanes, or anything else. Bleach-works, dye-works, print-works, and the like, all come under this category, and complete the circle of cotton manufacture.

The substitution of these comprehensive mechanical arrangements for the old-fashioned modes of handiwork has effected a mighty revolution in the social condition of the people. The history of that revolution is full of interest. Looking back at the Manchester people of bygone times, we see a notably industrious and independent race. Looking at them now, we see that both industry and independence have increased, in spite of changes fraught with danger and discomfort. A century ago the Lancashire spinners and weavers thought themselves superior to all the world—as, indeed, they were—in their craft. The craft gave them unusual freedom, and sufficient profit to ensure for them more luxuries than any other craftsman could enjoy. They looked with extreme jealousy upon the improved machinery that was introduced by Hargreaves, Arkwright, Crompton, and others, seeing clearly that thereby their cottage-workshops would soon be rendered impossible, and a new order of things would be introduced. Hence the Blackburn riots and other disturbances throughout Lancashire, which forced old Robert Peel and the other best friends of the cotton industries to use rough means for adopting the improvements and extending their trade. They succeeded, and the trade has been indeed extended. The cotton lords have, perhaps, in many cases, gained an unfair share of the benefit that has ensued, but the cotton operatives have also gained very much. They have found out the way to preserve their old independence, while they have come to be, in one sense, merely well-wrought tools in a vast conglomeration of machinery. You cannot walk through the streets of Manchester, or any other cotton town, without being struck by the self-sufficient bearing, the rough, honest look, and the almost painful intentness of purpose shown in every movement and aspect of every man, woman, and child. There is room for much further education, and especially hygienic education, among the cotton operatives; but England may be proud of them as they are, and the pride passes into reverence when we recall the history of their patient heroism, self-sacrifice, and mutual trust during the terrible period of the cotton famine, consequent on the American civil war.

Some mention of the multitudinous trades carried on in Manchester and its suburbs in dependence on the cotton manufacture, or apart from it, must be reserved for another paper.

VEGETABLE COMMERCIAL PRODUCTS.

VII.

PLANTS USED IN THE PREPARATION OF NUTRITIOUS AND STIMULATING BEVERAGES (*continued*).

GRAPE (*Vitis vinifera*, L.; natural order, *Vitaceæ*).—The wines of commerce are mostly prepared by fermentation from the juice of the grape. The vine ranks next to the tea and coffee plant in importance. The excellence of its fruit, whether fresh, or dried in the form of raisins, is well known. The virtues of its fermented juice have been eulogised in song by poets, and its excessive abuse has furnished a theme for moralists of every age and nation.

The grape varies in the colour, form, size, and flavour of its fruit. These varieties have all probably been produced by long-continued cultivation in different soils. This lengthened attention which the vine has received has given it an extensive geographical range. The vine may be found in all countries on the earth's surface included between the parallels of latitude 51° N. and 33° S. But the same latitude does not always permit the grape to ripen enough to make good wine; this depends on the average clearness or cloudiness of the atmosphere throughout the year.

The vine is generally supported by props and trellises, but in the sandy districts of Spain it is allowed to trail upon the ground. The time of the grape harvest, or vintage, is always regulated by the character of the wine to be made. For a brisk wine, such as champagne, the grapes are gathered before fully ripe; for a dry, full-flavoured wine, such as port, the mature grapes are selected; and for German wines, the driest of all wines, the vintage is made as late as possible. The process of wine-making is as follows:—

The grapes are gathered into baskets, which are emptied into a tub, with holes at the bottom, called the wine-press. This tub is placed over another much larger, named the wine-vat. A man then gets into the upper tub, and presses or crushes the grapes by treading upon them—a mode of bruising the grape as ancient as wine-making itself. The juice or *must*, as it is termed, flows from the press into the vat, and sometimes within a few days, or even a few hours, depending on the temperature, begins to ferment. This fermentation makes the liquor turbid, increases its temperature and volume, so that it quickly commences to fill the vat. After a time the fermentation ceases, the liquor diminishes in temperature and bulk, and becomes cool and clear. When quite cold it is drawn off, or racked, as it is termed, from the vat by a tap placed a few inches above the

bottom, into an open vessel, whence it is conveyed into the casks prepared for its reception. After entering the cask, a second, although much slighter, fermentation takes place, which further clarifies the wine; its subsidence diminishes the bulk of the wine in the cask, and more wine is added so as nearly to fill the cask. This again slightly renews the fermentation, and the cask is kept open until filled to its utmost capacity with wine free from fermentation; it is then closed, and is ready for the market.

It requires great attention and practical skill to manage the fermenting process properly, as on this depends the quality of the wine. Wines vary according to the amount of sugar, alcohol, and acid which they contain. When wines contain much sugar, they are called "sweet;" when little, "dry." Sweet wines, such as Malaga and Tokay, are wines which have been only half fermented; their sweetness depends on the fermentation not having exhausted the sugar. Dry, strong wines, such as Madeira, sherry, Marsala, and port, are fully fermented wines, all the sugar of the grape having been converted into alcohol. Champagne and other sparkling wines owe their briskness to the presence of carbonic acid; whilst hock and the Rhenish wines generally, and many of the French, contain much uncombined acid. The roughness and flavour of the red wines are usually derived from the husks of the fruit, but are often communicated to them by the addition of astringents, such as rhatany, kino, etc. The tints of wines are either natural or artificial. Their strength is frequently augmented by the addition of brandy. This brandy is itself distilled from wine. It is coloured with burnt sugar, and peach kernels are added during the distillation to give it that peculiar flavour by which it is distinguished.

The principal wine countries in Europe are France, Spain, Portugal, Germany, Sicily, Italy, Hungary, Greece, and Turkey.

France holds the first rank. The principal French wines are white and red champagne, white and red Burgundy, white and red Medocs from Bordeaux, Rhone wines, and wines from Languedoc, Roussillon, Orleans, Alsace, and Corsica. The inferior white wine of Bayonne, and Bordeaux wine, pass under the name of French wine, *vin ordinaire*.

From Germany we receive the celebrated Rhine wines, so called from their place of culture—the valley of the Rhine and its tributary streams; wines from the Palatinate, principally from Rhenish Bavaria; wines from the Bavarian province of Lower Franconia; Moselle wines from Rhenish Prussia; and Tauber wines from Baden and Wurtemburg. The chief places for these wines are Mayence, Coblentz, Frankfort-on-the-Maine, and Wurzburg.

The vine is cultivated to some considerable extent on the Danube in Lower Austria, also in Tyrol and Illyria; but the exportation is small. Moravia, Silesia, Bohemia, and Saxony grow inferior wines. Artificial champagne is made in many parts of Germany, especially at Esslingen, Stuttgart, and Mayence.

The best *Swiss wines* are the Ryff wines, from the Canton de Vaud, the *Vin de la côte* from the shores of Lake Geneva. Of *Hungarian wines*, Tokay is the chief, and is largely exported to Moravia, Silesia, Poland, and Prussia. Of *Spanish wines*, Malaga and Alicante are the most valued, and called after the names of the places which export them. From Oporto in Portugal we receive red and white port wine. Numerous varieties of Italian wines come into commerce. Europe also obtains Madeira wine from the island of Madeira, on the north-west coast of Africa; Cape (Constantia) wine from the Cape of Good Hope, and palm wine from the East Indies. Young and inferior wines, and the lees of wine, or the sediment at the bottom of the wine-vat, are used in the manufacture of cognac, or French brandy, and vinegar; these come into the market from Bordeaux.

In 1867 the import of wines into the United Kingdom amounted to 15,442,581 gallons.

Hops (*Humulus lupulus*, L.).—The hop vine, so well known in England, is a native of Europe, and probably also indigenous in North America, as it has been found growing apparently wild on the banks of the Mississippi and Missouri. It is extensively cultivated for its strobiles or cones, so largely employed in the preparation of malt liquors. These strobiles, or female catkins, when fully ripe, are picked from the vines, dried in kilns, and packed in bags. Hops consist of thin, translucent, veined, leaf-like bracts or scales, of a greenish-yellow colour, having near their base two small, round, dark seeds. Hops are somewhat narcotic and their odour fragrant, the taste bitter, aromatic, and slightly astringent. These properties are owing to the presence of a peculiar resinous secretion in the glands, which has been called "lupuline." Ale and porter owe their bitter flavour and tonic properties to the hops added to them during the process of brewing—about one pound of hops being added for every bushel of malt. About 550,000,000 gallons of ale and porter are annually brewed in this country. The importation of hops in 1867, chiefly from the Hanse Towns, Holland, Belgium, and the United States, was 975,168 cwt., as compared with 1,133,131 cwt. in 1860.

VI. PLANTS PRODUCING WHOLESOME AND NUTRITIOUS FRUITS.

The fruits of commerce are very numerous and interesting. They come to us from almost every climate and country; an immense amount of shipping is engaged in bringing them across the seas, and employment is thus given to hundreds of thousands of people. Besides furnishing us with nutritious food, these fruits give us much novel and interesting information in regard to the economy of vegetation in foreign countries. They are arranged naturally into two divisions, viz., fleshy fruits and nuts.

(*a*.) FLESHY FRUITS.

Of these one of the most important is the

Sweet Orange (*Citrus aurantium*, Risso; natural order, *Aurantiaceæ*).—This is one of our commonest foreign fruits. The orange-tree is a medium-sized evergreen, with alternate, bright-green, elliptical, pellucid-glandular leaves, furnished with winged footstalks; the flowers are white, and very fragrant. Both the ripe and unripe fruits are frequently seen on the tree at the same time along with the flowers—their presence amongst the foliage being truly ornamental, and adding greatly to its beauty. China is generally considered to be the native country of the orange-tree, where it still grows wild. It is said to have been brought to Portugal in 1520, and thence it has been transplanted into every country possessing climate suitable for its culture. It is now grown in China, Portugal, India, Northern and Southern Africa, Southern Europe, Turkey, the islands of the Mediterranean, the Azores, the West Indies, and the Southern portion of the United States.

The oranges imported into this country come chiefly from the Azores, Lisbon, Malta, Italy, Sicily, and Spain, in boxes and chests, and grow in those countries in the greatest profusion. It is said that a single orange-tree in St. Michael's has produced a crop of 20,000, exclusive of those unfit for use, calculated at 10,000 more. In 1866, 1,711,857 bushels of oranges and lemons were imported into the United Kingdom, valued at £889,238.

The rind of the orange yields by distillation a fragrant oil much used in perfumery; a still more agreeable oil, with which eau-de-Cologne is perfumed, is distilled from orange flowers. The rind is also boiled in sugar until it is candied, and thus converted into a sweetmeat. The orange contains much saccharine matter and mucilage, forming an agreeable acid, and hence is wholesome, cooling, and refreshing to the sick, especially in cases of fever and inflammation.

The Bitter or Seville Orange (*Citrus vulgaris*, L.).—This species closely resembles the sweet orange, but is easily distinguished from it by the form and bitterness of its fruit. These oranges are chiefly used in making marmalade. The rind has a place in the British Pharmacopœia from its qualities as a tonic.

Citron (*Citrus medica*, L.).—This kind closely approaches the lemon-tree in appearance, with which it has sometimes been confounded. The chief differences are its naked petiole, its greater number of stamens, and the superior thickness of the rind of its fruit. The fruit of the citron sometimes attains a very great size, weighing upwards of twenty pounds. The citron itself is not eaten, but the thick rind is much used as a preserve, and reaches England either already candied or else pickled in salt and water for the purpose of being candied on its arrival. We receive annually from Madeira about seventy tons of this preserved rind. An essential oil (*Oleum citronella*) is obtained from the rind of the citron, very fragrant, and much used in perfumery.

TECHNICAL DRAWING.—XIV.

DRAWING FOR JOINERS (*continued*).

FIGS. 145 and 146, combined into one view, are two designs for wooden gates, and are so simple that they will scarcely require any instructions as to copying.

The posts *m* and *n* are, of course, to be drawn first; then the base, *k*, and moulding, *l*; next the framing, *a*, *b*, *c*, *d*, of each gate.

In Fig. 145 the rail, *e*, is to be drawn next; and in the upper compartments the quatrefoils, *g*, and in the lower, the bars, *h*, and curved stay are to be drawn.

In the rectangle formed by the framing in Fig. 146 draw diagonals, and at their intersection the circular opening. Now draw the cross-framing, *o p*, and the vertical bars. The details will then be added without much difficulty.

GOTHIC TRACERY.

Although, as has already been stated, the whole subject of Gothic architecture, in both stone and wood, will be treated of in special lessons, still a few examples of tracery are given here, knowing that the joiner is often called upon to put such together on panels in churches or mansions, and that a knowledge of the basis of the construction will be of service to him. The limits of the present course of lessons, however, utterly preclude a systematic treatise on the characteristics of the several periods of mediæval art. These examples will, however, in some degree prepare the pupil for the subsequent and more extended study.

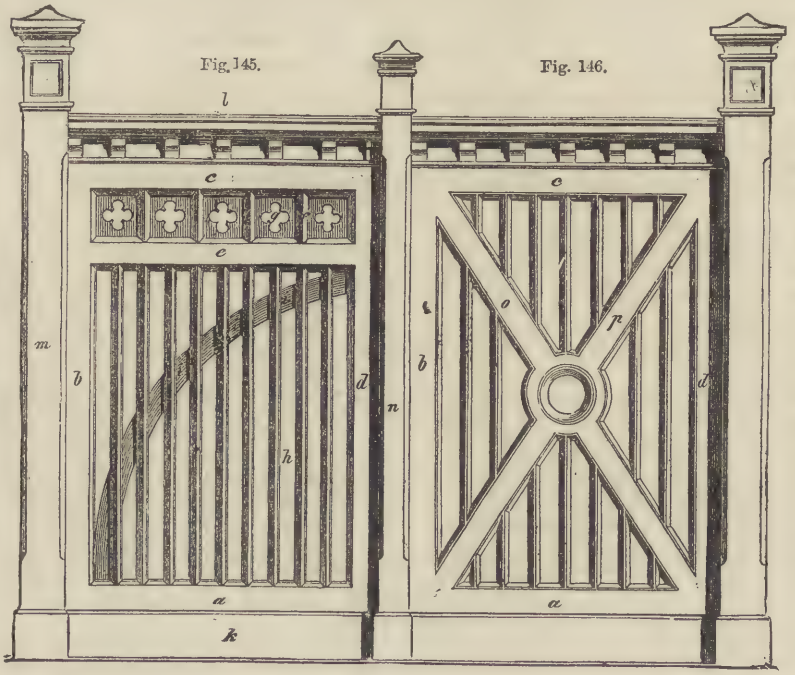


Fig. 145. Fig. 146.

Fig. 147 is the elementary figure upon which the subsequent design is based.

Having drawn the circle, describe on the diameter two opposite semicircles, meeting at the centre, *a*.

Divide one of these into six equal parts, and set off one of these sixths from *i* to *n*.

Draw *a n*, and divide it into four equal parts. From the middle point of *a n* draw a line passing through the centre of the semicircle, and cutting it in *c*. From *c* set off on this line the length of one of the fourths of *a n*.

This point and the two in *a n* will be the centres for the interior curves.

Fig. 148 is the further working out of this elementary figure. It is desirable that a larger circle should be drawn. Then, when the figure has been carried up to the stage shown in the last, all the rest of the curves will be drawn from the same centres.

Fig. 149 is the elementary form of the tracery shown in Fig. 151, and is based on the problem, "To inscribe three equal circles in a circle" (in "Practical Geometry applied to Linear Drawing"), which, in order to save the student the trouble of reference, in the event of his not being quite certain as to the construction, is here repeated in connection with Fig. 152.

At any point, as A, draw a tangent, and A G at right angles to it.

From A, with radius O A, cut the circle in B and C.

From B and C draw lines through O, cutting the circle in E and D, and the tangent in the point F (and in another not given here, not being required).

Bisect the angle E F A at F, and produce the bisecting line until it cuts A G in H. From O, with radius O H, cut the lines D C and E B in I and J. From H, I, and J, with radius H A, draw the three required circles, each of which should touch the other two and the outer circle.

Returning now to Fig. 149, having inscribed three equal circles in a circle, join their centres, thus forming an equilateral triangle. From the centre of the surrounding circle draw radii passing through the angles of the triangle and cutting the circle in points, as *d* and two others. Draw *e d*, and bisect it by *c g*; then the centres for the curves which are in the semicircle will be on the three lines *d c*, *c g*, and *c e*.

These curves are called *foliations*, or *featherings*, and the points at which they meet are called *cusps*.

The completion of this study is given in Fig. 151.

Fig. 150 shows the elementary construction of Fig. 153.

Draw two diameters at right angles to each other, and join their extremities, thus inscribing a square in the circle.

Bisect the quadrants by two diameters cutting the sides of the square in points, as *g*. Join these points, and a second square will be inscribed within the first.

The middle points of the sides of this inner square, as *b*, *c*, *d*, are the centres of the arcs which start from the extremities of the diameters.

From *b*, with radius *b d*, describe an arc, and from *g*, with radius *g c*, describe another cutting the former one in *e*. Then *e* is the centre for the arc *i g*, which will meet the arc struck from *b* in *i*. Of course, this process is to be carried on in each of the four lobes.

Fig. 153 is the completed figure. The method of drawing the foliation will have been suggested by Fig. 148, and is further shown in the present illustration.

Fig. 154 shows the skeleton lines of Fig. 155. Divide the diameter into four equal parts, and on the middle two, as a common base, construct the two equilateral triangles *o i n* and *o i m*.

Draw lines through the middle points of the sides of the triangles, which, intersecting, will complete a six-pointed star in the circle, the angles of which will be the centres for the main lines of the tracery.

Fig. 155 is the completed figure.

The small figures, 156 and 157, will be understood without further instruction than is afforded by the examples.

Fig. 158 shows the construction of the tracery in a square panel.

From each of the angles of the square (the inner one in this figure), with a radius equal to the length of the side of the square, describe arcs; these intersecting will give a four-sided curvilinear figure in the centre. Draw diagonals in the square.

From the point *b* where the diagonal intersects the curve (the middle line of the three shown in the figure) set off on the diagonal the length *b m* equal to *b c*.

From *q*, with radius *m q*, describe an arc *o m r*, cutting the original arc *x* in *o*.

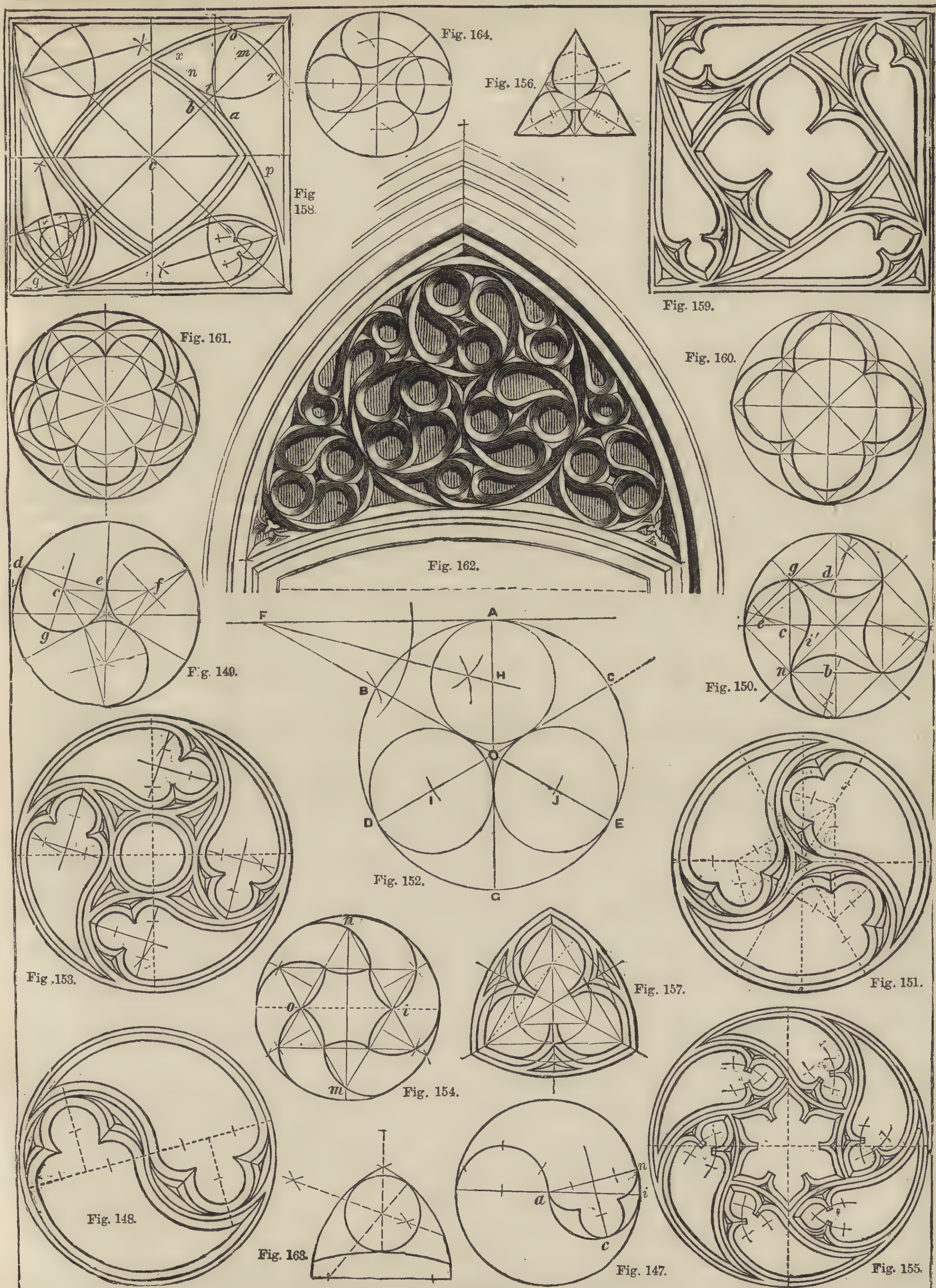


Fig. 164.
Fig. 156.
Fig 158.
Fig. 159.
Fig. 161.
Fig. 160.
Fig. 162.
Fig. 149.
Fig. 150.
Fig. 152.
Fig. 153.
Fig. 151.
Fig. 154.
Fig. 157.
Fig. 148.
Fig. 163.
Fig. 147.
Fig. 155.

Make *m r* equal to *m o*.

From *o* and *r*, with radius *o r*, describe arcs intersecting each other in *i*: extend these until they meet the curve *p* in *n* and *a*.

The foliation and completion, as per Fig. 159, will now be found simple

Fig. 160 is a quatrefoil, and Fig. 161 a cinquefoil, the construction of which has been fully described in "Practical Geometry applied to Linear Drawing" (Figs. 26 and 41).

Fig. 162 is given as a closing illustration of panel tracery; and it is hoped that, with the instructions already given, and the elementary figures 163 and 164, the student will be able to draw this example without further aid.

We shall in the next number commence a series of lessons in Drawing for machinists and engineers.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

VI.—SIR ROBERT STRANGE.

BY JAMES GRANT.

THIS eminent artist, the father of line engraving in Great Britain, was born on the 14th of July, 1721, in the island of Pomona, the principal of the Orkneys. He was lineally descended from Sir David Strange, or Strang, a younger son of the laird of Balcaskie, in Fifeshire, who had settled in those bleak northern isles at the time of the Reformation in Scotland. Under the care of Mr. Murdoch Mackenzie, teacher in Kirkwall, he received a classical education, and probably a knowledge of drawing, as his tutor has rendered good service to his country by the accurate surveys he published of the Orkney Isles, and of the British and Irish coasts. Young Strange was destined by his family for the study of the law; but, disliking the monotony of the profession, he shipped on board of a man-of-war, and sailed for the Mediterranean. However, he soon left the sea service, his great talent for sketching having shown him the propriety of making Art his study and occupation. On his return to Scotland some of his Mediterranean sketches were shown to Mr. Richard Cooper, an engraver in Edinburgh, who at once took him as an apprentice, and he soon made rapid progress in the arts. He felt that now he was, for the first time, in the line of life for which Nature destined him; but an interruption, for a time, was at hand. He was busy at his art on his own account, when in the month of September, 1745, the Highland forces of Prince Charles Edward took possession of Edinburgh, and blockaded the fortress. Strange had keen Jacobite predilections, all the more so that he had formed an attachment to a Miss Lumsden, sister of Andrew Lumsden, a Stuart partisan of note, who long afterwards formed one of Charles's exiled household at Rome, of the antiquities of which city he published an account. These circumstances, together with his local fame as an engraver, pointed him out as the most suitable person to undertake a print of Charles for his adherents and admirers; and while employed on this work, his house in Stewart's Close was the daily resort of the chiefs and officers of the revolted clans, and of all the ladies of high rank who were attached to their cause. The prince's portrait is still entitled to praise, but when completed it was regarded by the Scottish Jacobites as a miracle of art; yet to possess this portrait was once in itself treason. It was a half-length, in an oval frame, placed on a pedestal, whereon was engraved the legend,

"Everso missus succurrere sæclo."

As a reward for this service he was offered a place in the Finance department of the prince, but preferred an appointment in his Life Guards—a body of horse commanded by Lord Elcho, clad in blue faced with red, and with these he served throughout that romantic and desperate campaign. He was in the advance to Derby, and at the victory of Falkirk; and when riding along the shore, after the battle, had a narrow escape, as his sword was broken by a ball from a king's ship a little way out in the Frith of Forth. After the final defeat of the few insurgent clans at Culloden, he was obliged to conceal himself for many months among the Highland mountains, where he endured great hardships; but on the vigilance and cruelties of the Government toning down, he ventured back to Edinburgh and sought subsistence by selling his prints of the favourite Jacobite leaders who were in exile, and of those who had perished on the field or scaffold.

In 1747 he married Miss Lumsden, and they proceeded together to London; from thence they went to Rome, where many fugitive Scottish gentlemen, his comrades in the late struggle, were at that time residing, and there he obtained the honorary prize given by the Academy. After this Strange went to Paris, where he prosecuted his studies under the direction of Le Bas, from whom he had the first hint of the use of the instrument known as the *dry needle*, which he afterwards so greatly improved by his own genius.

The year 1751 found him in London, and settled as an engraver. He devoted himself almost entirely to historical, religious, or classical subjects, which he executed in a manner so masterly that he soon attracted considerable notice. As historical engraving had at that period made little or no progress in Britain, he may justly be deemed as also being the father of that most difficult department of art. In 1759, Mr. Allan Ramsay, a Scottish artist (son of the poet of the same name), now intimated to him that it would be agreeable to the Prince of Wales and Earl of Bute if he would undertake the engraving of two portraits he had just painted for those eminent personages. Mr. Strange, whose heart was still with the exiled Stuarts, declined, on the plea that he was about to start for Italy; and he is said to have thus lost the favour of the royal preceptor, which was afterwards of great disadvantage to him; though the king, at a future period, approved of his conduct, on the ground that the portraits, which were afterwards engraved by Ryland and Woollett, "were not worthy, as works of art, of being commemorated by him."

He had been long anxious to visit Italy, the seat of the fine arts, a second time; and in 1760 he set forth on his tour, in the course of which he made many drawings, which were afterwards engraved. While in Italy, he was chosen a member of the Academies of Rome, Florence, and Bologna, and was made a Professor of the Royal Academy at Parma, while at the same time he was elected a member of the Royal Academy of Painting at Paris. His portrait was introduced by Roffanelli, among those of other distinguished engravers, into a painting on the ceiling of the library in the Palace of the Vatican, where engravings are stored up; and he was permitted to erect a scaffold in one of the rooms of that princely dwelling—an unusual honour—that he might make a drawing of the "Parnassus" of Raphael—"a favour not granted for many years to any petitioning artist." The Pope assigned him apartments for his own use while engaged in this task; and the King of Naples conferred a similar honour upon him when he wished to copy a celebrated painting by Schedoni. His drawings were in coloured crayons—an invention of his own—and subsequently prints on a magnificent scale were published, from nearly fifty of the paintings he had thus copied in Italy. Among them may be mentioned: "The Return from Market," by Wouvermans; "Cupid," by Vanloo; "Mary Magdalene;" "Cleopatra;" "the Madonna;" "the Angel Gabriel;" "the Virgin with the Child asleep;" "Liberality and Modesty," by Guido; "Apollo rewarding Merit and punishing Arrogance," by Andrea Sacchi; "Joseph and Potiphar's Wife," by Guido; "Charles I.," by Vandyke.

The subsequent life of Strange was spent in London, where—owing to his Scottish birth and Jacobite sympathies—he did not find Court favour until 1787, when he was knighted by George III. A letter by him to the Earl of Bute, reflecting on some instances of persecution which he thought were traceable to that nobleman, appeared in 1775, and was prefixed to an "Inquiry into the Rise and Establishment of the Royal Academy of London," which was drawn from his pen by a law of that institution passed against the admission of engravings into the exhibition. Prior to this he had published "A Descriptive Catalogue of a Collection of Pictures" selected by him on the Continent. An authentic list of all his engravings will be found in the seventh edition of the "Encyclopædia Britannica."

Such was the chequered and busy life of our first line engraver; and after fifty years spent in the active exercise of his professional talents, he died of an asthmatical complaint, on the 5th of July, 1792, in the seventy-first year of his age, and was interred in the churchyard of Covent Garden. Besides his widow—one of those ladies who had seen the white cockade distributed at the Cross of Edinburgh—he left a daughter and three sons. "Sir Robert Strange has been described by his surviving friends as one of the most amiable and virtuous of

men, as he was unquestionably among the most able in his own peculiar walk. He was unassuming, benevolent, and liberal, and his industry was as remarkable as his talent. In the coldest seasons, when health permitted him, he went to work with the dawn, and the longest day was too short to fatigue his hand. Even the most mechanical parts of his labour he would generally perform himself, choosing rather to undergo a drudgery so unsuitable to his talents than trust to others."

AGRICULTURAL DRAINAGE AND IRRIGATION.—V.

By Prof. Wrightson, Royal Agricultural College, Cirencester.

MOLE PLOUGH—DRAINING TRENCH—DRAINING TOOLS, ETC.

In the last lesson we considered two methods of draining land, associated with the names of Elkington and Smith, of Deanstone, and concluded by giving a brief sketch of the materials used in forming underground channels. Such materials are, however, not always necessary, as it is possible to ensure a sufficient channel for water without their introduction, and also, in some cases, to dry land by open ditches. The last method of drainage need not detain us. Were we thoroughly to discuss it, we should be led into a very wide subject, embracing the surface drainage of upland pastures, the drainage of woodlands, where underground channels are not practicable, owing to the far-searching and insinuating character of the roots, and into the whole question of reclaiming marshes and fenny tracts. Under all these circumstances open ditches are used, and are occasionally of such magnitude as to resemble rivers and canals rather than ditches. Steam power is in such cases brought into requisition where the natural fall of the land is not sufficient to ensure an outfall, and the work assumes a magnitude requiring great engineering skill and a large expenditure of labour and capital. We must leave the consideration of such enterprises from sheer want of space, and restrict ourselves to more ordinary drainage operations.

With reference to the formation of underground channels without the use of tiles, stones, or any other material, two practices prevail. First, we have the *mole-plough* forcing its way through a tenacious clay, and leaving a hollow channel like the path of the animal after which it is named. Secondly, we have the drainage of peat, effected by leaving a space at the bottom of a trench.

Draining by means of the "mole-plough" is principally used in pastures resting upon a tenacious soil. It may also be employed as a means of drying arable land of similar character; but owing to the fact that such draining is necessarily somewhat shallow, and that arable soils are subjected to considerable pressure from the passage over them of horses and tillage implements, it follows that in their case a deeper and more permanent system is desirable.

Cheapness is the principal inducement for undertaking this work, the total cost being from £1 to £1 8s. per acre. The operation is effected by what may be termed a plough furnished with a stout coulter. This coulter, which is let down into the ground to the required depth, say thirty to thirty-two inches, is terminated by a conical or egg-formed piece of iron. The coulter cuts through the soil, and, after the passage of the implement, the earth again closes together, leaving the open channel, at the above-mentioned depth, caused by the passage of the "mole." The implement may be drawn by steam power, or by a wire rope wound around a capstan, on the headland.

Peat when drained is always liable to sink. Thus, at the November meeting of the Farmers' Club (1870), Mr. A. S. Ruston, of Aylesby House, Chatteris, informed his audience that the surface of Whittlesea Mere is seven feet lower than it was eighteen years ago, when the drainage works were commenced; and that "in the 'Middle Level,' on all our old-drained lands, we find the subsidence is still going on at the rate of an inch per year." While such a change of level is taking place, it would be unwise to adopt pipe-draining at the usual depths, as the lowering of the surface would subject the drains to injury from the treading of horses. The following plan is therefore used:—A trench is dug, thirty inches deep and twelve inches wide at the bottom. A narrow grafting tool (Fig. 4) is now used to deepen the trench, in such a manner as to leave shoulders on either side of the deepened portion. This is made plain by reference to Fig. 5. The sod taken from the surface is made to rest upon the shoulders just mentioned, and thus a hollow space is left as a drain. The trench is now filled up, and the work is complete (Fig. 5). In other cases, artificial channels are cut out of the substance of the peat by a tool constructed so as to form semi-cylinders of peat, which, when applied together and laid at the bottom of a trench, make a fair drain.

We have in the next place to consider the work of drainage as carried out upon the principles laid down by Mr. Smith of Deanstone. The tools with which the work is performed are worthy of consideration, and after briefly describing them we shall pass on to the consideration of the work itself. A line for marking off the work will be the first requisite in carrying out drainage work. The drainer will also require an ordinary spade (Fig. 7), which need not be de-

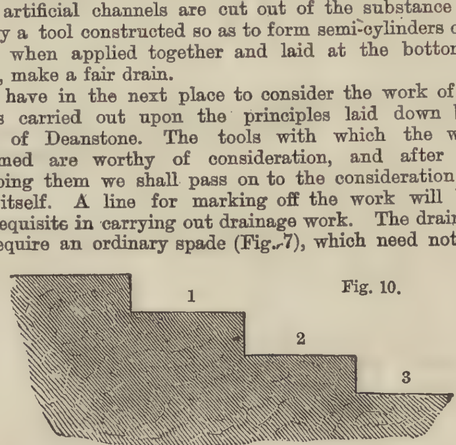


Fig. 10.

scribed. The remaining tools for making the trench consist of two grafting tools (Figs. 4, 6). These are so designed as to economise the amount of ground removed to the greatest possible extent. A glance at the sketches in the next page will show how the successive use of the spade and grafting tools must form a narrow trench, gradually decreasing in width with the breadth of the implements, until it is about four inches wide at the bottom. A shovel for paring and smoothing the sides (Fig. 7), a pickaxe for removing land-fast stones or cutting through rock, a "swan-necked" shovel for removing small fragments of earth and levelling the bottom of the trench (Fig. 8), a pipe-layer or wooden shaft, with a piece of iron at its extremity turned at right angles to the direction of its length (Fig. 9), a spirit-level, a drain-gauge for testing the depth of the trench, and a few boards and struts to support the sides of the trench where the ground happens to be of a very soft character. Such will be the most necessary tools with which to start the work of drainage.

We have now explained the benefits of the drainer's art, discussed the water economy of the soil, the best materials for constructing underground channels, and the work-tools required for carrying out the necessary operations. We proceed to the practice, first asking, How can we determine whether or not a field requires draining? Indications are numerous, both in the case of arable and of pasture lands. In the case of the former, wetness is indicated by the difficulty of working the soil for considerable periods after heavy rains have fallen. The ground cuts, or turns over from the plough in compact slices, whereas in contiguous and drained soils of similar quality the furrow is more friable, crumbling down after the passage of the plough. The undrained farm, therefore, cannot compete with its drier neighbour in the growth of root-crops, to which a fine tilth is absolutely necessary. Snow, too, has been observed to lie sooner and longer on undrained than on dry soils, owing to the difference in temperature between the two. When the drying March winds sweep over the country, the dry land speedily becomes white and dusty, while wet land keeps its black wintry colour, and continues uninviting to the sower.

Wet spots on hill-sides are indicated in the same way, and these spots may be identified all through summer by stunted herbage, deficient ears, and blighted grain. In the case of pastures, wetness is shown by sponginess under foot and a peculiar bleached appearance in the spring, when more favoured pastures are assuming a bright-green colour. The presence of sedges, rushes, and mosses all point in the same direction, and show that drainage is necessary. Accompanying these appearances in the land and herbage is a defective state of health in the live stock, and the prevalence of "quarter ill" among cattle and rot among sheep. Having then supposed a farm exhibiting such indications, it is high time to relieve it of its superabundance of water.

The first thing to be secured is a good outfall. This will be

fixed upon in accordance with the slope of the ground and the means of obtaining egress for the water. We assume the existence of a suitable beck, ditch, or rivulet sufficient for our purpose, and endeavour to select a sound portion of the bank happily placed for receiving the contents of our main-drain. This follows the line of the field's greatest depression. The furrow-drains flow into it, either on one or both sides, according to the contour of the ground. Where the slope of a field is evidently in a certain direction, all this is easily arranged; but where the fall is slight the eye cannot be trusted, and the "level" must be used. One yard in every 220 is an ample fall.* Having decided on the direction of the main and furrow drains, our next business will be to distribute tiles in small heaps at intervals along their proposed paths. Next, the work is commenced at the outfall by marking out with a line, and in the case of pasture land carefully removing the sod, and depositing it on one side. In arable land, the track of the drains may be marked out by the plough. Whichever method be decided upon, the cultivated soil or sod must be deposited upon one side, and the lower and less important soil upon the opposite side. The work commences at the outfall, represented in Fig. 10. One man steadily works backward, taking out the first spade's depth. A second labourer then commences at the outfall, standing in the trench made by the first man, and also working backwards, using the first grafting tool. A third man now commences at the outfall, with the bottoming tool, and taking out the last graff. Thus the work progresses from the outfall against the slope of the land, and in this way a clean-cut trench of uniform depth and width is excavated, the bottom being made smooth and level with the scoop or swan-necked shovel.

Fig. 8.

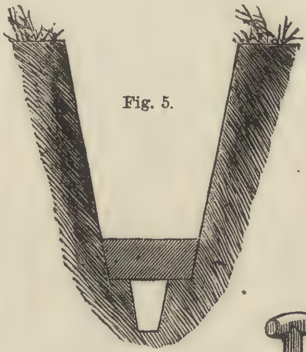


Fig. 5.

Fig. 4.

Fig. 6.

Fig. 7.

Fig. 9.

The depth of the drains, and the distance between the furrow-drains, are important questions in carrying out the work. With reference to depth, we recommend $3\frac{1}{2}$ to 4 feet as sufficient under ordinary circumstances. It is, however, not uncommon to find the strata of a field so arranged that a great advantage is secured by sinking the drains somewhat deeper. Mr. Girdwood writes as follows upon depth and distances apart of drains:—"I find it necessary to drain from eight to ten yards apart on the Weald and Oxford clays; at from ten to twelve yards on the clays of the Red Sandstone, where there is a uniform so-called homogeneous clay subsoil. In such cases the usual depth I employ is 4 feet for the minor drains, and 4 feet 3 inches for the mains. . . . In some of the gypseous clays in Derbyshire and Staffordshire I have gone to great depths. In one case, at Sudbury, the seat of Lord Vernon, I have drained about forty acres at a depth of from eight to eleven feet. The drains are sixty-six yards apart, and have been perfectly successful. I dug down at a dry time, finding no great rush of water till I got to about eight feet. It then began to flow, and at ten feet it rushed in with such force that the men had to be hauled up." Mr. Stephens, in his "Book of the Farm," says—"With regard to the distance between drains in a partially impervious subsoil, fifteen feet is as great a distance as a three-feet drain can be expected to draw, and in some cases I have no doubt that a four-feet one will be required. In more porous matter a three-feet drain will probably draw twenty feet with as great, if not greater effect; and in the case of a mouldy deep soil, resting on an impervious subsoil—which is not an uncommon combination of soils in the turnip districts of this country—a drain passing through the mould, and resting perhaps three or four inches in the impervious clay—which may altogether make it four feet deep—will draw, I have no doubt, a distance of thirty feet. More than thirty feet, I would feel exceedingly reluctant to recommend drains being made, unless the circumstances were remarkable." Furrow-drains, it is maintained, should not be more than 200 yards long; and if the slope down which they are brought is of much greater length, it will be advisable to break the distance—by running a main-drain across the line of slope, so as to carry off half the water—and to complete the drainage of the slope with a new series of furrow-drains.

The direction of the main-drains has been sufficiently indicated. That of the furrow-drains ought, as a rule, to follow the *line of greatest slope*. Such is the plan enforced by Government Inspectors of Drainage where the work is assisted by Government grants. In other cases, where the owner has full liberty to follow any plan that pleases him, it may be worth while to deviate slightly from this general rule when the old watercourses diverge from the line of greatest slope. A ruthless disregard to the path of old, long-used furrows has often been followed with mischievous consequences. There are, indeed, drainers who advocate crossing the line of greatest slope; but it may be readily shown that for a drain to exert its action equally on both sides, only one direction is possible—that of greatest slope.

Draining is a winter operation, and the work may be seriously impeded by heavy falls of rain or snow. It is for this reason that the work must be completed as it proceeds. No sooner is the trench opened than it must be prepared for the reception of the tile, by levelling the bottom, and making sure that water will be able to run down the trench without interruption. A practical mode of testing this is to empty a bucket of water at the head of the trench, and watch its course. Any small obstruction or hollow place may then be dealt with so as to ensure a perfect fall. The next point is to lay the tile. This work is usually committed to a superior man, or the foreman of the work, who, while he lays the pipes, must see that the trench is satisfactory in depth and levelness. Tiles must be laid and covered in up to the point where the work ceases, and the last tile laid should be stopped with a wisp of straw to prevent the entrance of anything which may obstruct the passage. Every tile should be perfect, and unworthy ones ought to be thrown aside. In the laying of main-drains, tiles three inches in diameter are in general use, and two-inch tiles are sufficient for furrow-drains. The furrow-drains are constructed upon the same principle as the mains, care being taken that the junction with the mains is secure and perfect. No two furrow-drains should open into the main exactly opposite to each other, as such a combination would be a cause of weakness in the main channel. Main-drains also should be three inches deeper than the furrow-channels, so that a rapid fall may be given at the confluence of the two.

* "Water will flow in large rivers with a fall of three inches in a mile."—*Robert Beart, Journal of the Royal Agricultural Society* (Vol. IV.).

PRINCIPLES OF DESIGN.—VI.

By Christopher Dresser, Ph.D., F.L.S., etc.

HARMONIES AND CONTRASTS OF COLOUR (*continued*).

In my last chapter we commenced the consideration of the harmonies and contrasts of colour, and set forth the laws governing its application to objects by axiomic propositions; and the principles taught in these axioms were illustrated diagrammatically.

With the view of continuing this diagrammatic form of illustration, and of impressing upon the mind the statements made in my former chapter, and with the further view of familiarising my readers with this mode of study in the hope that they may apply it to my essays on the various manufactures, I shall make manifest the quantities in which the various colours harmonise: thus:—

Blue.	*Red.*	*Yellow.*
O O O O	O O O O	O O O
O O O O	O	
Blue		*Orange.*
O O O O	harmonises with	O O O O
O O O O		O O O O
Red		*Green.*
O O O O	harmonises with	O O O O
O		O O O O
		O O O
Yellow		*Purple.*
O O O	harmonises with	O O O O
		O O O O
		O O O O
		O
Purple		*Citrine.*
O O O O	harmonises with	O O O O
O O O O		O O O O
O O O O		O O O O
O		O O O O
		O O O
Green		*Russet.*
O O O O	harmonises with	O O O O
O O O O		O O O O
O O O		O O O O
		O O O O
		O O O O
		O
Orange		*Olive.*
O O O O	harmonises with	O O O O
O O O O		O O O O
		O O O O
		O O O O
		O O O O
		O O O O

To those who are about to practise ornamentation, it is very important that they have in the mind's eye a tolerably accurate idea of the relative quantities of the various colours necessary to harmony, even where the colours are considered as existing in a state of absolute purity. We have rarely, however, to use the brightest blues, reds, and yellows which pigments furnish, and even these are but poor representatives of the potent colours of light as seen in the rainbow, and with the agency of the prism; nevertheless, a knowledge of the quantities in which these pure colours harmonise is very desirable. The proportions in which we have stated that colours perfectly harmonise, and in which the primary colours combine to form the secondaries, and the secondaries the tertiaries, are given in respect to the colours of light, and not of pigments or paints, which, as we have just said, are more or less base representatives of the pure colours of light. Yet certain pigments may, for our purpose, be regarded as representing pure colours. Thus, the purest real ultramarine we shall regard as blue (cobalt is rather green, that is, it has a little yellow in it; and the French and German ultramarines are generally rather purple, or have a little red in them, yet the best of these latter is a very fine colour), the purest French carmine as red (common carmine is frequently rather crimson, that is, has blue in it, or rather scarlet having yellow in it; vermilion is much too yellow), and lemon chrome as yellow (the chrome selected must be without any green shade, and without any orange shade, however slight); and these pigments will be found to represent the colours of the prism as nearly as any that can be found. I would recommend the learner to get a small quantity of these colours in their powder form, substituting the best pale German ultramarine for real ultramarine, as the latter is of such a high price,* and to fill the various circles of our diagrams, which represent the primary colours, with these pigments, mixing them with a little dissolved gum arabic and water. The secondary colours will be fairly represented by pale-green lake, often called drop-green, by orange-chrome—that of about the colour of a ripe, rather deep-coloured, orange rind—and the purple by the admixture of pale German ultramarine and crimson lake, in about equal proportions, with a little white to bring it to the same depth as the green. I cannot name any pigments which would well represent the tertiary colours. Citrine is about the colour of candied *lemon* peel; olive about the colour of candied citron peel, and russet is often seen on the skin of certain apples called "russet apples," in the form of a slight roughness; but this russet is in many cases not quite sufficiently red to represent the colour bearing the same name. Iron rust is rather too yellow. This colour should bear the same relation to red that the candied lemon-peel does to yellow.

If the student will try carefully to realise these colours, and will fill up the circles in our diagrams with them, he will thereby be much assisted in his studies; but it will be still better if he prepare fresh diagrams on a larger scale, and use squares instead of circles. I should recommend, and that I do strongly, that the student work out all the diagrams which we have suggested on a tolerably large scale, using the colours where I have used words. I should also advise him to do an ornament, say in red on a gold ground, and outline this red ornament with a deeper red; to do a gold ornament on a coloured ground, and outline it with black; and indeed to carefully work out an ornamental illustration of our propositions, Nos. 24, 25, 26, and 27, and to keep these before him till he is so impressed by them as to *feel* the principle which they set forth. This should be done on a large scale in all our designing-rooms and art-workshops.

As we shall have to refer to colours by naming pigments, and as I am constantly asked what pigments I employ, I shall enumerate the paints in my colour-box; but I shall place a dagger† against those which I have in my private box, and which I do not supply in my offices; but these I seldom use. Of yellows I have king's yellow† (not a permanent colour), very pale chrome,† lemon chrome (about the colour of a ripe lemon), middle chrome (half-way between the lemon and orange chrome), orange chrome (about the colour of the rind of a ripe orange), yellow lake,† Indian yellow.† Of reds—vermilion, carmine, crimson lake. Of blues—cobalt,† German ultramarine, both deep and pale, Antwerp blue, indigo. Of greens—emerald, green-lake, pale and deep. Of browns—raw Turkey umber, vandyke, Venetian red, purple-brown, brown-lake. Besides these I have what is called celestial blue, which is a very pure and intense turquoise, vegetable black, flake white, and gold bronze.

There are certain facts connected with the mixing of colours which must never be lost sight of; thus, while the colours of light co-mingle without any deterioration, or loss of brilliancy, pigments or paints will not do so, but by admixture tend to destroy one another. This takes place only to a small extent

* Real ultramarine is sold at £8 per ounce. The best imitation, or German ultramarine, is procurable at any oil-shop at about 3s. to 4s. per pound. The best carmine should be procurable at 6s. per ounce, but artists' colourmen often charge £1 1s., owing to the small demand for this pigment. The best chrome yellow (this is kept in many shades) is about 1s. 6d. per pound.

when but two primary colours are combined; but if any of the third primary enters into the composition of a tint, a decided deterioration, or loss of intensity, occurs.

For this reason we employ many pigments, so as to get as little mixing of colours as we can. But there is another reason why the great admixture of colours is undesirable. Colours are chemical agents, and in some cases the various pigments act chemically on one another. Of all colours yellows suffer most by admixture with other colours; but this is accounted for by their delicacy and purity. For this reason I use a greater variety of yellow pigments than of red or blue.

Were it possible to procure three pigments devoid of chemical affinities, and each of the same physical constitution, as of equal degrees of transparency or opacity, the one truly representing the blue of light, another the red, and another the yellow, we should need no others, for of these we could form all other colours; but as no pigments come even near to the fulfilment of these conditions, we have to employ roundabout and clumsy methods of arriving at our ends.

Were I inquiring into the laws of colour with a view to scientific ends, I could here point out a number of most interesting facts; but while I must not do so, I am happy to say that another writer is contributing a series of papers to the journal in which I write, taking the scientific view of colour; and I would urge upon my readers the desirability of studying these contributions, for there they will find the explanation of facts which I can only mention.

I hesitate to proceed, lest I should not have made my meaning sufficiently clear respecting points on which I have touched; and before I do so I think that it will be safer if I extend my remarks respecting certain statements; for there is always the fear of supposing that, because one happens to be familiar with a certain subject, others, who have never before thought on the matter, must at once catch his meaning, even if given almost in the bare form of a hint; and it is certainly safer to err on the side of excessive elucidation than on that of poverty of explanation.

There is one statement which I made in my last paper that, perhaps, needs a little elucidation, although the careful student may have seen the reason of my statement. I said that purple harmonised with citrine, green with russet, and orange with olive. I might have expressed it (and many would have done so) thus:—The complement of citrine is purple, the complement of russet is green, and the complement of olive is orange. A colour which is complementary to any other is that which, with it, completes the presence of the three primary colours: thus green is the complement of red, and red of green, for each, together with the colour to which it is the complement, completes the presence of the three colours. But in order to a harmony, the complement must be made up in certain proportions. Let us now refer to our second diagrammatic table in my last article, and we there see that citrine is formed of two equivalents of yellow and only one equivalent of red and of blue. Now, in order to a harmony, each primary should be present in two equivalents, as one is present in this quantity—*i.e.*, the yellow. One equivalent of blue and one of red (both of which are wanting in the citrine) form purple; hence purple is the complement of citrine, or the colour that with it produces a harmony. In russet one equivalent of blue and one of yellow are wanting, and these in combination are green—green, then, is the complement of russet. And in olive one equivalent of red and one of yellow are wanting—red and yellow form orange, hence orange is the complement of olive.

I have spoken of all colours as of full intensity and purity, but we have to deal also with other conditions. All colours may be darkened by black, when *shades* are produced; or reduced by white, when *tints* are produced. Besides these alterations in intensity, a portion of one colour may be added to another. Thus, if a small portion of blue be mingled with red, the red becomes a crimson or blue-red; or if a small portion of yellow be added to the red, the latter becomes a scarlet or yellow-red. In like manner, when yellow is in excess in a green, we have a yellow-green; or when blue is in excess, a blue-green; and so with the other colours. Such alterations produce *hues* of colour.

We now come to the subtleties of harmony. Thus, if we have a yellow-red or scarlet—a red with yellow in it—the green that will harmonise with it will be a blue-green; or if we have a blue-red, a crimson—a red with blue in it—the green that will harmonise with it will be a yellow-green. This is obvious, for the following reasons:—Let us suppose a red represented by the equivalent number, five, with one part of blue added to it, thus causing it to be a blue-red or crimson. Were the red pure, there should be eleven parts of green as a complement to the five of red, of which green eight parts would be blue and three yellow; but the blue-red occurs in six parts, one of which is blue—there are, then, but seven parts of blue remaining in the equivalent quantity to combine with the three of yellow, one being already used; hence the green formed is a yellow-green, one of the equivalents of blue necessary to the formation of a true green being already in combination with the red, and thus absent from the green.

The same reasoning will apply to the scarlet-red and blue-green, and, indeed, to all similar cases; but to take the case of the crimson-red and yellow-green, as just given, and carry it a stage further, we might add two parts (out of the eight) of blue to the red, and make it more blue, and then form the complementary green of six parts of blue and three of yellow, and thus make it more yellow. Or we may go farther still, and add to the red six of the eight parts of blue, when the admixture would appear as a red-purple rather than as a blue-red, in which case the complementary green—or, rather, green-yellow—would consist of two parts of blue and three of yellow. These facts are diagrammatically expressed in the following:—

Red. OOOOO / O *Blue.*	*Crimson* harmonises with	*Yellow-Green.*	*Yellow.* OOO / OOOOOOO *Blue.*

Or,

Red. OOOOO / OO *Blue.*	*Blue-Crimson* harmonises with	*Very Yellow Green.*	*Yellow.* OOO / OOOOOO *Blue.*

Or,

Red. OOOOO / OOOOOO *Blue.*	*Red-Purple.* harmonises with	*Green-Yellow.*	*Yellow.* OOO / OO *Blue.*

In all these cases it will be seen that we have eight parts of blue, five of red, and three of yellow, only the mode of combination varies. This variation may occur to any extent, provided the totals of each be always the equivalent proportions.

These remarks will apply equally to hues of colour, shades, and tints, and to shades and tints of hues.

Care, and perhaps a little practice, will enable the learner to arrange colours into a number of degrees of depth, or shades, as they are generally called. (We do not here use the term as signifying pure colours darkened with black.) Ten shades of each colour differing obviously in degree of depth can readily be arranged by the experienced, the ten shades being equidistant from each other as regards depth—that is, shade 3 will be as much darker than shade 2 as shade 2 is darker than shade 1, and so on throughout the whole. Purple is a colour intermediate between blue and red. Imagine ten hues between the purple and the red, and ten more between the purple and the blue: thus we should have purple, then a slightly red purple, then a rather redder purple, then a purple still more red, and so on till we get purple-reds, and finally the pure red; and the same variations of hue at the blue side also. Imagine, further, the green having ten hues extending towards blue, and ten more stretching towards the yellow; and the orange having ten hues towards the red, and ten towards the yellow—in all cases I count the colour from which we start as one of the ten, thus:—

Blue.									Purple.									Red.
0	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	0

—and we shall have 54 colours and hues of colour. Of each of these 54 colours and hues imagine 10 degrees of depth, and we get 540 colours, hues, tints, and shades, all differing from one another to an obvious degree.

Mark this fact, that any colour, tint, hue, or shade of such a diagram has its complement in one other of the colours, tints,

hues, or shades of the diagram, and that only two of this series of 540 are complementary to each other; thus, if you fix on any one colour of the 540, there is but one colour in the whole that is complementary to it, and it is complementary to but this one other colour.

The student will do well to try and make a colour-diagram of this kind, of a simple character, say such as the following, only using pigments for my numbers; but in doing so he must exercise the utmost care, in order that he secure some degree of accuracy of tint or shade, and if he can call to his aid an experienced colourist it will be of great assistance to him.

This table is highly valuable, as it gives ninety harmonies, if carefully prepared in colour; and the preparation of such a table is the very best practice that a student can possibly have.

Let us for a moment consider this table, and suppose that we want to find the complement to some particular colour, as the third shade of red. We find the complement of this in the third shade of green opposite. If we want the complement of the second shade of orange-yellow, we find it in the second shade of blue-purple opposite, and so on. Thus we have a means of at once judging of the harmony of colours.

FORTIFICATION.—IV.

BY AN OFFICER OF THE ROYAL ENGINEERS.

TRACE OF WORKS—DEFINITIONS OF VARIOUS METHODS OF ARTILLERY ATTACK, AND MODES OF OBTAINING PROTECTION FROM THEM.

Before considering the varieties of trace suitable for works under different circumstances, it will be well to examine the ways in which artillery and musketry fire can be employed for their attack and defence, and then what defensive arrangements can be made to guard against these. Various terms are employed to express the direction, mode of firing, and special objects of artillery fire, with reference to the works attacked. Thus the terms *direct*, *oblique*, *reverse*, *enfilade*, *flanking* all express the horizontal direction of the fire; whereas *plunging*, *pitching*, *vertical*, and *ricochet* denote varieties either in the mode of firing, or the results to be attained.

The terms *direct* and *oblique* are applied to the fire of guns placed either immediately opposite or oblique to the direction of the works attacked.

Reverse fire is that which is brought to bear on the interior of a work by guns firing into it from the rear. When the guns of the assailants are so placed as to bring either a direct or oblique fire to bear on the works, they must be opposed by parapets of sufficient strength and thickness to resist them; but when protection from reverse fire is required, it becomes necessary to construct a sort of second parapet inside the work, behind the guns, which is called a *parados*.

When the enemy's guns are in prolongation of the line of work attacked, and can fire along the rear of that line, it is called *enfilade* fire. This is a very effective method of artillery attack, as any one shot may take effect on many more guns or men than it could if it merely passed directly through the parapet. To guard against this, great care should be taken in tracing a work that the prolongations of the lines of parapet are directed on to points inaccessible or beyond the range of the enemy's guns. Where this is impracticable, short earthen parapets, called *traverses*, must be built at right angles to the general line, to intercept the shot.

Ricochet fire is that in which the charge and elevation of the guns are so arranged as to cause the shot to make a number of rebounds after its first graze in the work. It is consequently often employed for enfilading purposes.

When a line of parapet is so placed that the fire from its guns passes parallel to and in front of another line, it is called a *flank*, and defends that line by a flanking fire. A glance at

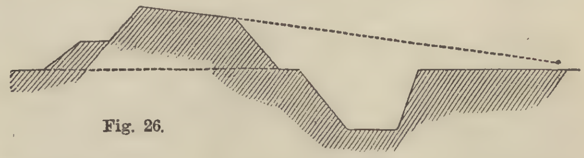


Fig. 26.

any ordinary profile (Fig. 26) will show that the ditch cannot be defended by the direct fire of the parapet behind it, and unless the ditch is defended by a flank fire from some other part of the work, the enemy might assemble in comparative safety in it before making his final assault. This defence is obtained either by means of flanks or by constructions in the ditch, and it is with reference to it that most of the varieties in the trace of works other than those dependent on the shape of the ground are made.

Vertical fire is that from mortars firing shells at an angle of 45° so as to fall almost vertically. This is the least accurate of all the artillery fire we shall have occasion to consider, but is useful for bombarding towns, closed works, etc., where great accuracy is not essential. Protection from the effects of vertical fire can only be obtained by constructing buildings, the roofs of which are of sufficient thickness to resist the fall of the shells from a great height, and their subsequent explosion. In all works intended to make a prolonged resistance to modern artillery, protection of this kind, or "bomb-proof cover" as it is called, must be largely provided. When these buildings are of a permanent nature, they are called *casemates*, and where only temporary constructions, *blindages*. As a guide to the thickness of roof necessary for this purpose, it may be well to remember that the maximum penetration of the largest spherical shells in the British service (13 inches) was found to be as follows, viz.—penetration in earth, 6 feet; in concrete or brickwork, 1 foot 6 inches.

Pitching fire is similar to ricochet, except that the shot descend at such an angle as not to rebound. It is used in the attack of works, to strike objects that are hidden from view by some intervening mass, over which the shot must pass. Escarp walls and other masonry in permanent fortifications are liable to be breached by this means, unless they are kept considerably below the direct line of fire.

Plunging fire is that from guns firing with full charges at objects on a much lower level than themselves. Owing to the considerable angle of depression of the guns the shot do not ricochet, and greater accuracy in firing is required; it is not, therefore, very efficient against troops or small moving objects, but is most effective against ships, whose guns probably cannot elevate sufficiently to reply, and whose decks, even in iron-clads, are rarely invulnerable. The Russian "Wasp" battery, which did so much damage to the English ships bombarding Sebastopol, was an example of this. Undoubtedly the advantages of a commanding position are so considerable, and the difficulties of protecting the interior of a work from plunging fire are so great, that none but urgent reasons can justify works being placed in so disadvantageous a position; it must not, however, be supposed that a slight difference of level constitutes plunging fire, or that a work is necessarily untenable because it is somewhat lower than the attacking guns; for the Russian lines at Sebastopol withstood for more than a year the attack of the Allies, whose artillery was posted on a higher level than they were.

The object of almost all works being that of enclosing or protecting some particular area, it follows that few can consist of a mere straight line of parapet, and their trace or outline shape will depend—

1. On the number of men they are intended to hold.
2. On the shape of the ground.
3. On the necessity for flank defence for the ditches and ground in front.

The trace will, therefore, either be a curved line or consist of a number of lines forming angles with one another. When an angle points outwards from the work it is called a *salient angle* (Fig. 27); and when it points inwards, a *re-entering angle.* The former should be as obtuse as possible, and never less than 60°.

The imaginary line bisecting a salient angle is termed the *capital.*

The distance from a flank to the furthest point of the work flanked by it, measured in the direction of the flanking fire, is called a *line of defence.* The length of this line is dependent on the weapons used, although, as the same accuracy can never be obtained from men who are being fired at as from ordinary target practice, it is made considerably less than the effective range of these arms. In field-works, therefore, the lines of defence should not, as a rule, be more than 200 yards long; and in permanent works, where the ditches are flanked by artillery,

with intervals (Fig. 29). Closed are better than open works for this latter case, unless there is a second line of works behind the first, in which case the gorges of the open works must be closed by obstacles, to prevent the enemy, by a temporary success, getting possession of them, and dismounting the guns or doing other damage before retiring.

In permanent works an attack on the rear of the open works in connection with the fortress can rarely be made, owing to the formidable nature of the ditches that surround them

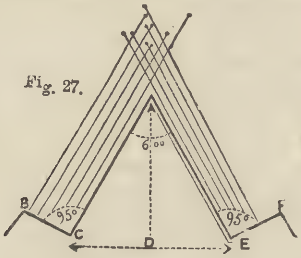
When closed works are employed in the outer line, their gorge parapets should be made so thin as not to prevent the guns of the rear-line firing into them.

The principal descriptions of open works employed in field defences are—*redans*, *flêches*, *double* or *triple redans*, and *lunettes;* and in permanent fortification more formidable works, answering the same purpose if not exactly of the same shape, are employed, called *ravelins*, *lunettes*, *horn works*, and *crown works.*

Redans, *flêches*, and *ravelins* are all of much the same form, and consist of two lines of parapet meeting in a salient angle.

A *redan* is a large field-work of this shape; whereas a *flêche*

Fig. 27.



C A E, salient angle; A D, capital; C E, gorge; B C E F, flanks; B C A, A E F, re-entering angles, or flanking angles, or angles of defence; C A, line of defence.

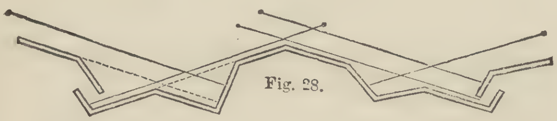


Fig. 28.

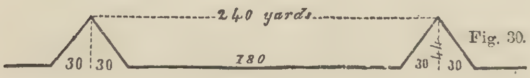
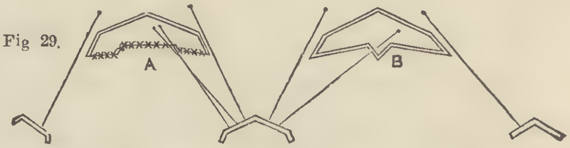


Fig. 30.

Fig 29.



A, open-work gorge closed by obstacles; B, closed work.

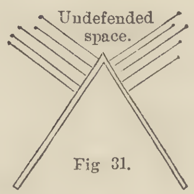


Fig 31.

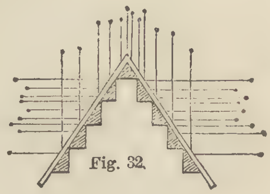


Fig. 32.

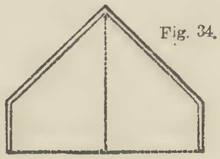


Fig. 34.

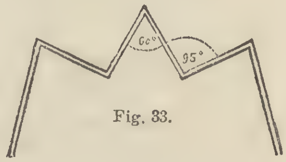


Fig. 33.

they may vary from 300 to 500 yards, so as to be within range of case and grape-shot.

The angle between a flank and a line of defence is called the *flanking angle* or *angle of defence.* This should never be less than a right angle, lest accidentally oblique fire should wound men defending the parapet that is being flanked; and should not exceed 95°, as the fire would then become too divergent.

When the parapets of a work entirely surround the site occupied, and its garrison is consequently capable of an independent resistance, no matter on which side the attack may be made, it is called a *closed work;* and when its parapets only afford a defence in certain directions, leaving an open side or *gorge* liable to attack, it is called an *open work* (Fig. 28).

Closed works are suitable for isolated positions, and should, if possible, have their own flank defence. Open works are chiefly used as auxiliaries to other works, to afford a flank defence for the approaches to them, and are themselves defended by the flank-fire of the works in rear, which should be able to fire into their open gorges and prevent an enemy occupying them.

Both open and closed works are frequently combined so as to mutually defend one another, for the occupation of a long line or position. They are then called *lines of intrenchments.*

If a number of open works are connected by a line of parapet or obstacles, they are called *continuous lines;* and if the works are isolated and the spaces between them only defended by the fire of the collateral works or works in rear, they are called *lines*

is a smaller work, intended merely to protect a gate or some similar small object. In Fig. 30 is shown Vauban's Redan line, consisting of redans 180 yards apart, connected by a straight line of parapet.

A *ravelin* is a permanent redan-shaped outwork, placed in advance of a permanent fortification to increase its defensive powers.

All these works have the defects of being liable to be enfiladed, of being open at the gorge, and of having the space in front of the salient angle badly defended. This is owing to the fact that men firing over a parapet deliver their fire at right angles, or nearly so, to the crest (Fig. 31).

This undefended space may be brought under fire by the addition of short auxiliary flanks (see Fig. 29), or by forming a short face at right angles to the capital. In some cases where the front fire of a ravelin may be much wanted, and its flank fire required in a direction at right angles to the capital, this principle may be still further applied (see Fig. 32).

A *double* or *triple redan* consists of two or three redans combined as one work (Fig. 33). In these the flank defence of the salients is provided for, but the outer faces on either side are unflanked. A *lunette* is a redan with two extra faces parallel to the capital (Fig. 34). It is useful as an advanced outwork, but has all the defects of other open works.

Open works are specially adapted for the protection of bridges or other positions where they cannot be attacked in rear. They are then called *têtes du pont* or bridge-heads.

BUILDING CONSTRUCTION.—VIII.

ARCHES (*continued*).

THE *semi-circular arch* was the kind of arch principally used by the Romans, who employed it largely in their aqueducts and triumphal arches. Other forms, however, are mentioned by some writers as having been employed by the ancients. In the Middle Ages forms still different to those already in use were generally introduced. Thus we have—

The *stilted arch*, which it is scarcely necessary to say is but an adaptation of the semi-circular, the springing being raised above the capitals of the columns. The illustration below (Fig. 55), copied from Mr. Owen Jones's admirable handbook to the Alhambra Court of the Crystal Palace, will afford the student a good example of this species of arch.

Next we have the *horseshoe arch*, also used in, and almost entirely restricted to, the Arabian style of architecture. In this form of arch the curve is carried below the line of centre or centres; for in some cases the arch is struck from *one* centre, and in others from two, as in Fig. 56.

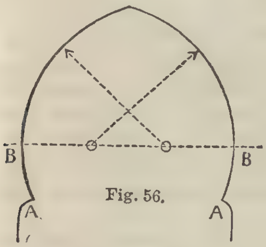


Fig. 56.

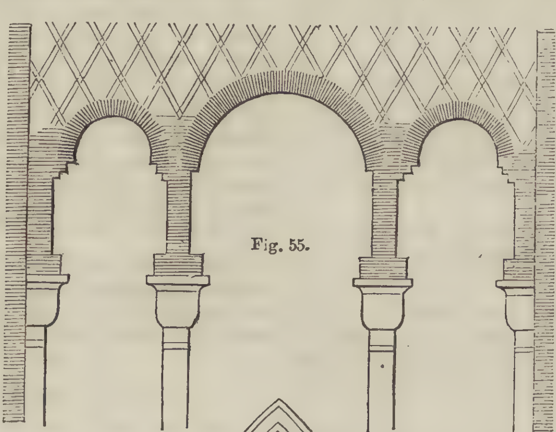


Fig. 55.

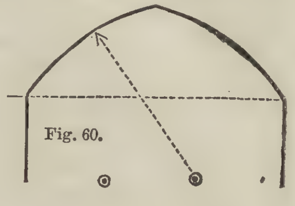


Fig. 60.

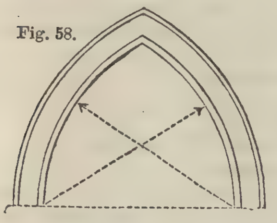


Fig. 58.

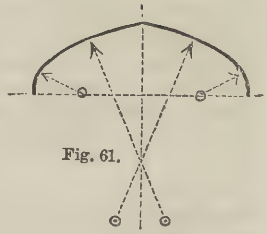


Fig. 61.

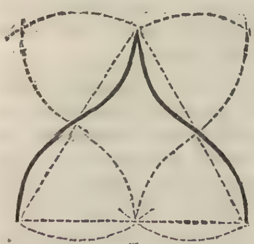


Fig. 59.

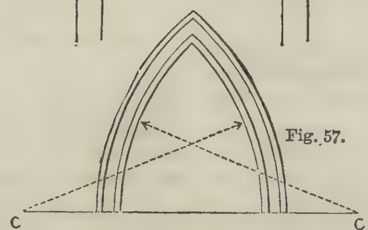


Fig. 57.

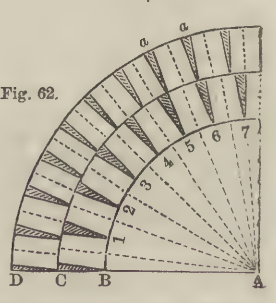


Fig. 62.

Now it must not be supposed that the real bearing of the arch is at the imposts, A, A; for if this were really so, it must be seen that any weight or pressure on the crown of the arch would cause it to break at B; but the fact is simply that the *real* bearings of the arch are at B, B, and the prolongation of the arch beyond these points is merely a matter of form and has no structural significancy. The horse-shoe arch belongs especially to the Mahometan architecture, from its having originated with that creed, and from its having been used exclusively by its followers.

Next in point of time, but by far the most graceful in form, is the *pointed arch*, which is essentially the mediæval (or middle age) style, and is capable of almost endless variety. The origin of this form of arch has been the subject of much antiquarian discussion; but it is certain, that although the pointed arch was first generally used in the architecture of the Middle Ages, recent discoveries have shown that it was used many centuries previously in Assyria.

The greater or less acuteness of the pointed arch depends on the position of the centres from which the flanks are struck.

Thus the *lancet arch* (Fig. 57) is constructed by placing the centres C, C outside the span, but still on the same line with the imposts. This form of arch was first used in the Gothic, and as a rule indicates the style called "Early English," which prevailed in this country from about 1189 until 1307.

Fig. 58 is the *equilateral arch*, the radius with which the arcs are struck being equal to the span of the arch, and the centres being the imposts; and thus, the crown and the imposts being united, an equilateral triangle is formed. This form was principally used in the "Decorated" period of Gothic architecture, from about 1307 until about 1390, at which time the *ogee arch* (Fig. 59) was also occasionally used.

At a later date, during the existence of the "Perpendicular" style of Gothic architecture—viz., from the close of the fourteenth century to about 1630—we find various forms of arch introduced, such as the *segmental* (Fig. 60), formed of segments of two circles, the centres of which are placed below the springing; and still later on we find the *Tudor* or four-centred arch (Fig. 61), in which two of the centres are on the springing and two below it. The arches at the later period of this style became flatter and flatter, and this forms one of the features of Debased Gothic, when the beautiful and graceful forms of that style gradually decayed, and for a time were lost. Happily, in the present century there has been a gradual and spirited revival of the Gothic style, and works are now being produced which bid fair to rival in beauty of form and in principles of construction the marvellous buildings of the Middle Ages. As the principles of Gothic Architecture will form the subject of another series of lessons, further description is here unnecessary.

We now return to the constructive principles of arches, and these may be conveniently treated of under the separate heads of brick arches and those constructed of stone, the main principles being the same—viz., that the bricks or stones composing the arch must be so placed that they act as wedges. In stone arches, this is accomplished by cutting the stones into the exact forms required. In bricks, they must either be "gauged," that is, rubbed or cut to the shape required, or the difference must be made up by mortar; the skill of the workman being in this case displayed by his so bonding his courses that the shrinking may be equally distributed, and that when the necessary settlement is arrived at, the structure may be found perfectly safe and strong.

Arches in brickwork are *plain*, *rough*, and *cut* or *gauged*.

Plain arches are built of uncut bricks, and these being blocks of equal thickness, must be "made out" with mortar (Fig. 62, *a a*); that is, the difference between the intrados and the extrados must

be filled in with mortar or cement. Thus, in building such an arch, the bricks at the inner line should all but touch, and the centering (the wooden framework upon which the arch is temporarily built) should not be struck (or removed) until the arch has settled or the cement perfectly hardened. The cement used should be of greater consistency than for general purposes. In consequence of the unavoidable defect in plain brick arches—viz., that the bricks are not in themselves wedge-like in form, but are kept apart at the top by a matter liable to shrink—it is advisable in extensive and continuous works, such as tunnels, sewers, vaults, etc., to make them of thin independent rings of half-brick or one-brick thick—that is, a 9-inch arch should be in two half-brick arches, as is shown in the illustration (Fig. 62), and an 18-inch arch should be formed of rings consisting of alternate whole and half-bricks, the bricks being put in where they come naturally, as where three, four, or more bricks of the inner ring cut in with four, five, or more of the outer ring; but by half-bricks we do not, in this case, mean bricks *cut* into halves, but merely laid on their edge, as *headers*, so as to be *half-brick high*. Each arch thus becomes bonded in itself with headers and stretchers, as in a brick wall.

Rough arches are those in which the bricks are roughly cut with an axe to a wedge form, and are used over openings, such as doors and windows, when the work is to be plastered on the outside, or in plain back-fronts, outhouses, garden gates, etc.; when, however, they are generally neatly finished off with what is called a "tuck joint." This consists in marking the divisions by a neatly-raised line of fine white plaster, having previously pressed a blue mortar into the joints.

Pointing is of two kinds, *tuck*, as above, and *flat*. This last consists in first raking out the mortar in front of the joints, and filling in with mortar, on which the line is then marked with the edge of the trowel.

Semi-circular and elliptical arches, when large, are generally formed of uncut bricks; but those composed of small segments of circles are either cut or axed. These are sometimes called *scheme arches*. Very flat arches are known by the name of "camber," from the French word *cambrer*, to round like an arch.

Gauged arches are formed of bricks which are cut and rubbed to gauges or moulds, according to a full-sized drawing of half an arch. Gauged arches are, of course, the neatest in appearance, and are therefore used in the fronts of houses.

When the arches are semi-circular, the bricks will all be of one shape, and therefore, if the number of arches renders it worth while, the bricks may be all moulded; that is, made specially of the exact size and form required. The arches over windows in fronts of houses are frequently *straight*. Such a window with a diagram (Fig. 63) will be shown in the next lesson. The outer slant line of the arch is called the *skew-back*, and, as a rule, the skew-backs of both sides should meet on the centre line, at an angle of 60°. From the drawing it will be seen that the material between the two arcs struck from H is all that is really efficient in forming the arch, and that all between the arc and its chord is of no service. This breadth may be increased by making the angle at the centre less than 60°—that is, taking the centre lower down on the perpendicular line; the skew-back will not then slant so much, and the width at the crown will be more, the arch being flatter; but that portion will be less secure than by the former system, for, as the radii diverge less, they are more nearly parallel, and hence are not so tightly wedged together. These arches require to be executed with the utmost nicety, being generally of only half a brick thick, and not being bonded to the work behind them. Bricklayers usually cut the joints of gauged arches slack at the back, so as to get a fine joint on the face; the consequence is that the pressure of the load causes the arrises of the face to chip, and thus the bricks fall out; this should therefore be guarded against.

DRAWING FOR BRICKLAYERS.

In accordance with the plan laid down—viz., that the cuts in these lessons should serve not only as illustrations of the text, but as studies for drawing—we now proceed to give the student some instructions as to the method of drawing the subjects used as architectural illustrations.

One illustration previously given may, however, require a few hints to guard the student against error, viz., Fig. 62.

The subject of this is a "plain arch," that is, one in which the bricks are not cut or altered in form, but are still made to *radiate*; that is, the intrados of the arch is to be made smaller than the extrados, for otherwise an arch could not be formed; and here it is to be remembered that the difference between the small intrados and the larger extrados is made up by mortar or rough pieces of bricks, but that the bricks themselves retain their original size.

Now to draw such an arch :—

The radius of the intrados being given—viz., A B—from A, with radius A B, describe the semicircle, half of which is here shown, and also the semicircle C; the width between these two semicircles being equal to the width of a brick laid on its broad side, viz., 4½ inches by scale.

Divide the intrados into as many equal parts as there are to be bricks in the inner ring of the arch; viz., 1, 2, 3, 4, etc.

It will be evident that the *centres* of these bricks radiate from the centre of the circle, though their sides do not.

Therefore, bisect each of the spaces 1, 2, 3, 4, etc., and draw radii through these bisecting points.

Now, if a line were drawn along the end of a brick it would be at once seen that the edge of the top and bottom surface would be *parallel* with this line, and of course with each other; therefore, from points 1, 2, 3, 4, etc., draw lines *between* the semicircles, *parallel* to the radii. This may easily be done with a pair of set-squares, by the method shown in the lessons in "Technical Drawing;" and thus a semicircle of oblongs will be obtained—that is, approximately so; for were this drawing executed on a larger scale, it would be seen that the inner and outer edges of the ring are made up of pieces of straight lines equal to the width of the shorter edge of the end of each brick.

For the second ring, mark off the width C D, equal to B C; set off on the semicircle C the width of the narrow sides of the bricks, as at 1, 2, 3, 4, etc.; bisect these spaces, and draw lines parallel to the bisecting lines as before.

CIVIL ENGINEERING.—III.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

WATER-WORKS.

THE term *water-works* is properly applied only to such works as have for their object the collection, supply, and conveyance of water to towns for drinking and sanitary purposes, but it is also applicable in a somewhat subordinate degree to the storage and utilisation of water for agricultural objects.

We have adverted to that great work of Egyptian engineering, Lake Mœris, which was intended as a reservoir to receive the waters of the Nile at the period of overflow, to be employed afterwards for the irrigation of the surrounding district. In all countries where the rainfall is confined to certain seasons, and is then excessive, it is imperative to provide against the effects of the dry season. In Hindostan, where the greatest periods of drought occur at certain cycles of years, the construction of reservoirs has been carried to an extreme that is not found in any other country. Advantage has been taken of every nook and ravine, and, by throwing across them banks of earth called *bunds*, they have been converted into storage reservoirs. In the Madras Presidency alone, there exist at the present time upwards of 43,000 irrigation reservoirs available for use, whilst thousands besides have become useless through neglect. The length of these bunds varies from half a mile to thirty miles. The Poniary tank, now disused, was formed by the construction of a *bund* thirty miles across the opening of a valley, and embraced an area of nearly eighty square miles. The Veranum reservoir is still in operation, and possesses an area of thirty-five square miles, the bund which effects the storage being twelve miles long. In the island of Ceylon there exist the remains of an embankment constructed for storage purposes fifteen miles long, composed of huge blocks of stone cemented together, 100 feet wide at the base, and sloping to a top width of forty feet.

These semi-natural reservoirs are to be found in our own island, but in smaller proportions, as, for instance, in the Pentland Hills, where one such reservoir forms the principal source of water-supply to Edinburgh.

In determining the position for a reservoir of this kind, there are several matters which require consideration irrespective of the formation of the ground. It will be necessary to determine—

1. What is the height of the proposed reservoir with respect to the town or district to be supplied from it? 2. What is the nature of the soil composing the proposed site; is it porous or otherwise? 3. What is the source of supply; is it regular, being derived from springs, or irregular, being dependent upon rainfall; and if the latter, may a sufficient amount be expected to be available in all ordinary periods of dry weather? 4. What are the difficulties to be encountered in conveying the water from the reservoir to the town?

The question of rainfall is one of the highest importance in matters of water-supply. As a rule, the rainfall is greatest in those districts which are situated towards the coast-line, whence the prevailing winds blow. For instance, in Great Britain and Ireland, the south-western districts are the most rainy; but the presence of mountains which penetrate the cool moisture-charged regions of the air causes the atmosphere to part with its moisture by condensation, and hence the rainfall occurs on the *lee* side of the mountains. The rainfall over the whole globe varies in different localities from zero to 28 feet per annum.

In addition to the foregoing considerations, if the water-supply of a town is to be *entirely* dependent upon a storage reservoir, it will be necessary to determine its loss by absorption and evaporation, and then to proportion its area accordingly. The average *annual* loss by evaporation in the temperate zone, with a mean temperature of 52·25°, is 36·5 inches. In South America, with a mean temperature of 81·86°, it exceeds 100 inches. The mean *daily* evaporation in Great Britain is less than ·1 inch.

Equal in importance to proportioning the storage area to the demand, is the consolidation of the embankment, so as to withstand the pressure of water under every possible emergency. Neither is it enough to determine what will be the water-pressure, and to proportion the breadth and slope (*batter*) of the earth-work to the strain upon it; the character of the material composing it is equally important, for above all things *percolation must be prevented.* The *least trickle* may be the commencement of wide-spread desolation. It is not necessary that the entire mass of the bank should be impervious to water, but there must run throughout it an impenetrable layer. Well-puddled clay will answer the purpose, and the most advantageous position of this layer is on the side of the bank *next* to the water, its surface being protected from detrition by a closely packed layer of stones. The main body of earth lies upon the reverse side of the puddled wall, its use being simply to act as a buttress or support to it, all that is laid upon the water-side becoming valueless as a support, since the water will penetrate it.

A regularly-constructed *weir* or escape-pipe for the overflow must be provided, so as to prevent the water escaping over loose or removable soil, and if it be an escape-pipe or culvert it should not pass *through* the bank, as there is always a tendency to trickle along the line of pipe. A syphon passing *over* the bank may be employed with advantage, and may be kept always full and ready for use by a valve at the base of the longer leg.

Having thus briefly considered the question of water-supply derived from a level *above* that of the district to be supplied, we shall now consider how best to obtain and utilise it from a *lower* level.

There are few towns in existence which have not a river or stream of some kind either passing through or very near them, and these would naturally appear to offer the means of water-supply. But when we remember that the same streams are very generally the channels employed to convey away the sewage and refuse matter, the idea of using the water for drinking purposes vanishes. It is, however, possible under certain conditions to render such water drinkable. Nature has provided that the soil itself shall act as a filter and disinfectant to water passing through it; if, therefore, a reservoir be constructed of a soil suitable for filtration, and the impure waters be pumped into it and allowed to filter through it into another receptacle, and the same process repeated through other reservoirs, the water may be rendered fit for use. There is, of course, a limit to this process of purification, for there are streams so highly contaminated and indeed poisoned by the infiltration of chemical and animal impurities that no amount of artificial filtration will make their water pure. The black, stinking streams which flow through our northern manufacturing towns are long past all recovery as affording drinkable water. We are not, however, dependent upon streams and rivers for an efficient water-supply. The action of the soil in purifying water extends to the rainfall, which, absorbed by the ground, passes downwards by gravitation, and, being obtained from a considerable depth, is found to be highly suitable for the use of man; and here we have the great and never-ceasing water-supply, always and almost everywhere available, which Nature herself provides for us.

We are thus led to a brief consideration of wells. These are various in contruction. There is the *ordinary* dug well, and the *bored* or *Artesian* well.

Of ordinary dug wells there is the *shallow pit* into which surface water drains; such is little better than a *cesspool*, not deserving of the name of well, and yet thousands of our population are wholly dependent upon such means for their water-supply, the use of which is a fruitful source of disease and death. Some of our most fearful epidemics may distinctly be traced to the use of water derived from such a source.

The construction of *deep* wells is of very ancient date. The ancient wells of Cabul are from 300 to 350 feet deep, and many of them are only 3 feet across. A dug well at Tyre is *said* to be 3,780 feet deep. Jacob's well at Samaria is 105 feet deep and 9 feet in diameter. Joseph's well at Cairo is a wonderful piece of engineering skill. It consists of two shafts, one above the other, but not in the same vertical line. The upper shaft is 165 feet deep, and 24 feet by 18 feet in the opening. At the bottom is a spacious chamber cut down into the rock, which serves as a reservoir for the water raised from the lower shaft, which is 130 feet deep, and 15 feet by 9 feet in the opening. This second shaft is sunk at the side of the reservoir, and is reached from the surface by a spiral gallery cut in the solid rock *outside* the upper shaft, the gallery being pierced with loopholes opening into the shaft to afford light. By this gallery pass the men and mules which raise the water from the lower shaft, and discharge it into the reservoir, whence it is raised to the surface. The mode of raising the water is the same in both the shafts, and consists of the ancient Eastern system of an endless band of twisted grass passing over a large drum suspended over the mouth of the well, and lashed to which are earthen jars having their mouths all in the same direction. The drum is caused to revolve by animal labour, and the jars which descend empty come up filled, discharging their water into a trough as they pass over the drum.

The mode of construction of ordinary wells is as follows:—If the soil is of a sandy or loose nature, the sides of the well must be protected by a lining or *steining*, the most suitable materials for which are timber, stone, brick, and iron. Timber, which should be elm, may be employed as a preliminary support, or as a steining in saline strata, the salt preventing its decay. Under other circumstances timber is objectionable, as it is subject to rot. If stone is employed, it should be silicious. Brickwork is the material most usually employed, but if the water in the surrounding soil be impure, or if under considerable pressure, it is not suitable, as the water will percolate. The use both of brick and stone is, in fact, rather to keep back the *soil* than the water. Of all materials iron is the best by far for a steining. It is capable of bearing great strains and resisting great pressure; water cannot pass through it, and it is not liable to decay.

The steining of wells, whether of brickwork or of iron, is performed in sections. If of bricks, the earth is taken out to as great a depth as is consistent with safety, and a "curb," or circular ring of jointed timber, is placed on the bottom, upon which is laid the brickwork which is carried up to the surface. The curb is suspended by iron rods to cross-beams laid over the mouth of the shaft, and is capable of being lowered bodily with the brickwork upon it when required. The earth below the curb is now removed, and the steining is gradually lowered, more brickwork being added above. This process is thus continued until, if the well is deep or the soil very loose, the friction of the earth outside prevents the steining sinking lower by its own weight; it is then said to be "earth-bound." The excavation must now be continued below the first curb, and a second section of brickwork laid upon a second curb must be commenced below the upper piece, this being suspended independently of the first, and lowered in the same manner. Another mode of proceeding is to leave a portion of earth below the first curb to support it, and after a further excavation, the diameter

of which is equal to that of the *inside* of the steining, to insert a fresh curb at a certain distance below the first, and gradually removing the earth above it, to fill in the space with superposed brickwork until the first curb is reached. When iron is employed it is usually the *cast* metal, the steining being cast either entire as a cylinder, or in sections. If the latter, the sections are cast with flanges pointing *inwards*, by means of which they are bolted together, the joints being made water-tight by iron cement. The outer surface of the cylinder is thus smooth, and it may be driven down to a considerable depth before becoming earth-bound. The great advantage of a steining through which water will not percolate is that all surface and impure water is shut out from the well, and the water obtained only from the deep-seated springs, which are usually pure.

The most useful well is the *bored* or Artesian well. Bored wells are of very ancient date. They are to be found in all parts of the world, and have existed in Egypt, China, and other Eastern countries from time immemorial. There is a well bored on this principle at the old convent of Chartreux, in the town of Lillier in France, which is said to have been executed as far back as the year 1126. The *rationale* of the Artesian well is easily explained. Certain soils—such as sand, gravel, chalk—are absorbent, and permit water to pass through them; others—such as clay, loams—are non-absorbent, and do not permit the water to pass through them. Hence the rainfall is arrested in certain directions, and finds a free passage in others. But the tendency of water is to flow in *all* directions, and it will therefore move along horizontal strata if debarred from sinking lower by a clay formation. Water under these circumstances may, and often does, find its way laterally *beneath* a bed of clay or rock, and if the clay or rock be perforated, the underlying water will spring up, rising to a height equal to the height of water pressing upon it *anywhere* outside the clay. Suppose, then, a perforation be made in the soil, passing through various strata, but coming at length to a clay or rock stratum, the probabilities are greatly in favour of water rising in the bore from below the clay, and frequently to a height quite near the surface. There are even instances of the water rising *above* the surface, and forming a perpetual fountain of the purest water.

The mode of well-boring is simple, although tedious and expensive. The boring tool, which is of steel, is attached to an iron rod, to which a rotary motion is imparted. As the depth of the bore increases, the rod is lengthened by the addition of successive pieces attached one to the other by firmly-screwed joints. The shape of the boring tool varies with the kind of stratum it has to contend with. If it be rock, the tool is shaped like a chisel, so as to cut and break the stone; if clay, the tool is shaped like an augur, which scoops it out. The broken soil has to be brought to the surface by tools specially adapted for the work. The great loss of time lies in raising and lowering the tool, which has frequently to be done, and in recovering a broken tool, every portion of which must be removed before the work can proceed. The Chinese adopt a system of "jumping" in boring for water. The rod is suspended by its upper end to a windlass placed some feet above the bore, and is frequently raised and allowed to fall, a rotary motion being applied to the rod at the same time. The plan is very effectual, but the tool suffers frequent fracture.

Bored wells are only a few inches in diameter, and have in certain strata to be protected by iron steining. The joints of the successive sections of the tube are necessarily "flush" both inside and out, the mode of uniting them being shown in Fig. 2,

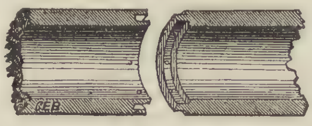


Fig. 2.

so as neither to prevent their sticking in the soil, nor yet to impede the action of the boring rod, nor the subsequent flow of water.

The supply of water obtainable from Artesian wells is frequently enormous. At Birkenhead, one such well, about 400 feet deep, yields 2,000,000 gallons of good water in twenty-four hours. Another at Kingston-on-Hull, which is sunk in chalk to a depth of 281 feet, and having a diameter of 18 inches for 210 feet of this depth, yields nearly 4,000,000 gallons in the same period. A well was commenced on Southampton Common some years since, and attained a depth—partly by digging, and partly by boring—of 1,317 feet from the surface, but water not being then obtained, it was abandoned.

In all cases of water-supply for towns it is essential to provide reservoirs to meet any sudden demand for it which may arise from fire, etc., or to provide against injury to the pumping machinery. The size of the reservoir must depend entirely upon circumstances.

The mode of disseminating the water over the district to be supplied must be briefly noticed. At the present day the water is conveyed in cast-iron pipes, the diameter and thickness of which are proportioned to the demand likely at any time to arise, care being taken to allow a fair margin for increase of population. In the early days of the New River Company, the water was conveyed in *wooden* troughs under the streets. The Company

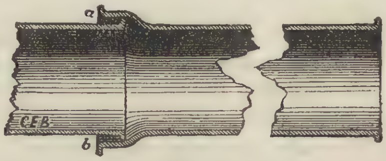


Fig. 3.

possessed at one period 400 miles of this troughing, but the leakage was so great—equal to one-fourth of the original supply—owing to faulty joints, decay of material, and bursting after frost, that they were abandoned.

The joints between the pipes have to be made with great care to prevent leakage; they are made after the pipes are bedded in their place, and the ground must be taken out at each joint to an extent to permit a man to pass entirely round it. The pipes are cast with a lip at one end, and an enlargement at the other, as shown at Fig. 3, so that the end of one fits into the enlargement of the other, as seen at *a b*. Into the recess thus formed, a flat plait of spun yarn is driven with a caulking chisel and mallet, and melted lead run into the remaining space. The principal arteries or pumping mains are the largest and strongest, and have frequently to bear a very great pressure. From these mains branch off pipes of lesser size and diminished thickness, and from these again others smaller and thinner, and so on. The valves which regulate the supply consist for the most part of a sliding plate of iron, fitting accurately in a vertical groove, and raised or lowered by a rod working in a stuffing-box. The pressure of the water being thus at right angles to the plane of movement, it exerts a comparatively small influence upon it, whilst the surface of friction is greatly less than in an ordinary tap. A throttle or balance valve could not be rendered water-tight.

When the reservoir stands upon the same or a lower level than the system of pipes through which the water has to pass, great care is necessary to render the flow in them equable. The action of the pumping-engine being intermittent, the flow of water would be reduced to a series of impulses, by which great strain would be thrown upon the machinery, without some means of keeping up the forward motion of the column of water between each stroke of the engine. There are two methods of doing this, by fixing either a vertical stand-pipe or an air-chamber over the main immediately in front of the pump. The action of the pump impels a certain quantity of water forward into the main, but the *vis inertia* of the mass of water opposes a certain amount of resistance to this effort, and some therefore rises into the stand-pipe—which is open at the top—or into the inverted air-chamber. In the case of the stand-pipe, the column of water takes up the force, which for a moment the engine has ceased to apply, and continues to urge forward the water in the main. In that of the air-chamber—which is simply a large and strong iron cylinder closed at the top, and communicating below with the main—the water is forced by the engine partly into the main, and partly into the air-chamber, thereby compressing the air, which, directly the pump stops, acts by its elasticity upon the water it contains, and thus continues its forward motion in the main.

PRINCIPLES OF DESIGN.—VII.

By Christopher Dresser, Ph.D., F.L.S., etc.

HARMONIES AND CONTRASTS OF COLOUR (*continued*).

Continuing our studies in colour-harmony, it must be noticed that while colours harmonise in the proportions stated, the areas may vary if there be a corresponding alteration in intensity. Thus eight of blue and eight of orange form a perfect harmony when both colours are of prismatic intensity; but we shall still have a perfect harmony if the orange is diluted to one-half its strength with white, and thus formed into a tint, provided there be sixteen parts of this orange of half strength to the eight parts of blue of full strength.

The orange might be further diluted to one-third of its full power, but then twenty-four parts would be necessary to a perfect harmony with eight parts of prismatic blue; or to one-fourth of its strength, when thirty-two parts would be necessary to the harmony.

It is not desirable that I occupy space with diagrams of these quantities, but the industrious student will prepare them for himself, and will strive to realise a true half-tint, quarter-tint, etc., which is not a very easy thing to do. By practice, however, it will readily be accomplished, and anything achieved is a new power gained.

What I have said respecting the harmony of blue with tints of orange will apply in all similar cases. Thus red will harmonise with tints of green, provided the area of the tint be increased as the intensity is decreased; and so will yellow harmonise with tints of purple under similar conditions.

But we may reverse the conditions, and lower the primary to a tint, retaining the secondary in its intensity. Thus blue, if reduced to a half-tint, will harmonise with orange of prismatic intensity in the proportion of sixteen of blue to eight of orange; or, if reduced to a quarter-tint, in the proportion of thirty-two of blue to eight of orange. Red, if reduced to a half-tint, will harmonise in the proportion of ten red to eleven of green; and yellow as a half-tint in the proportion of six yellow to thirteen of purple.

The same remarks might be made respecting the harmony of shades of colour with those of prismatic intensity. Thus, if orange is diluted to a shade of half intensity with black, it will harmonise with pure blue in the proportion of sixteen of orange to eight of blue, and so on, just as in the case of tints; and this principle applies to the harmony of all hues of colour also.

To go one step further: we scarcely ever deal with pure colours or their shades or tints, or even come as near them as we can. With great intensity of colour we seem to require an ethereal character, such as we have in those of light; but our pigments are coarse and earthy—they are too real-looking, and are not ethereal—they may be said to be corporeal rather than spiritual in character. For this reason we have to avoid the use of our purest pigments in such quantities as render their poverty of nature manifest, and to use for large surfaces such tints as, through their subtlety of composition, interest and please. A tint the composition of which is not apparent is always preferable to one of a more obvious formation. Thus we are led to use tints which are subtly formed, and such as please by their newness and bewilder by the intricacy of formation.

To do what I here mean it is not necessary that many pigments be mixed together in order to their formation. The effect of which I speak can frequently be got by two well-chosen pigments. Thus a fine series of low-toned shades can be produced by mixing together middle-chrome and brown-lake in various proportions, and in all of the shades thus formed the three primary colours will be represented, but in some yellow will predominate, and in others red; while in many it will not be easy to discover to what proportionate extent the three primary colours are present.

Let us suppose that we make a tint by adding white to cobalt blue. This blue contains a small amount of yellow, and is a slightly green-blue. But to this tint we add a small amount of raw umber with the view of imparting a greyness* or atmospheric character. Raw umber is a neutral colour, leaning slightly to yellow—that is, it consists of red, blue, and yellow, with a slight excess of the latter. In order that an orange harmonise with this grey-blue of a slightly yellow tone, the orange must be slightly inclined to red, so as to neutralise the little green formed by the yellow in the blue. It may harmonise with the grey-blue as a pure tint if the area of the diluted and neutralised primary is sufficiently extended, or may itself be likewise reduced to a tint of the same depth, when both tints would have, in this instance, the same area.

I might go on multiplying cases of this character to almost any extent, but these I must leave the student to work out for himself, and must pass on to notice that while it is desirable to use subtle tints (often called "broken tints"), it is rarely expedient to make up the full harmony by a large area of a tertiary tone and a single positive colour. Thus, we might have a shade or a tint of citrine spreading over a large surface as a ground on which we wished to place a figure. This figure would harmonise in pure purple were it of a certain size, and yet if thus coloured it would give a somewhat common-place effect when finished, for the harmony would be too simple and obvious. It would be much better to have the nineteen parts of citrine reduced, say, to half intensity, when the area would be increased to thirty-eight, with the figure of eight parts of blue and five of red, than of thirteen parts of purple.

But it would be better still if there were the thirty-eight parts of reduced citrine, three parts of pure yellow, thirteen of purple, five of red, and eight of blue, together with white, black, or gold, or all three (these may be added without altering the conditions, as all act as neutrals), for here the harmony is of a more subtle character.

If we count up the equivalents of the colours employed in this scheme of harmony, we shall see that we have, in the citrine—

Yellow	6	(two equivalents).
Blue	8	(one equivalent).
Red	5	(one equivalent).

In the purple—

Blue	8	(one equivalent).
Red	5	(one equivalent).

Of the pure colours—

Yellow	3	(one equivalent pure).
Red	5	(one equivalent pure).
Blue	8	(one equivalent pure).

Thus we have three equivalents of each primary, which give a perfect harmony.

I must not say more respecting the laws of harmony, for the space at my disposal will not allow of my so doing, but must proceed to notice certain effects or properties of colours, which I have as yet only alluded to, or have passed altogether unnoticed.

I have said that black, white, and gold are neutral as regards colour. This is the case, although many would suppose that gold was a yellow. Gold will act as a yellow, but it is generally employed as a neutral in decorative work, and it is more of a neutral than a yellow, for both red and blue exist largely in it. The pictorial artist frames his picture with gold because it, being a neutral, does not interfere with the tints of his work. It has the further advantage of being rich and costly in appearance, and thus of giving an impression of worth where it exists.

Black, white, and gold, being neutral, may be advantageously employed to separate colours where a separation is necessary.

Yellow and purple harmonise, but yellow is a light colour and purple is dark. These colours not only harmonise, but also contrast as to depth, the one being light and the other dark. The limit of each colour, wherever these are used in juxtaposition, is therefore obvious.

It is not so with red and green, for these harmonise when of the same depth. This being the case, and red being a glowing colour, if a red object is painted on a green ground, or a green object on a red ground, the "figure" and ground will appear to "swim" together, and will produce a dazzling effect. Colour must assist form, and not confuse it. It will do this in the instance just named if the figure is outlined with black, white, or gold, and there will be no loss of harmony. But experience has shown that this effect can also be averted by outlining the figure with a lighter tint of its own colour. Thus, if the figure is red and the ground green, an outline of lighter red (pink) may be employed. (See Proposition 26.)

* Cobalt, raw umber, and white make a magnificent grey, both in oil-colours in tempera (powder-colours mixed with gum-water) and in distemper (powder-colours mixed with size).

A blue figure on a red ground (as ultramarine on carmine), or a red figure on a blue ground, will also produce this swimming and unsatisfactory effect, but this is again obviated by an outline of black, white, or gold.

Employing the outline thus must not be regarded as a means of merely rendering what was actually unpleasant endurable, for it does much more—it indeed affords one of the richest means of effect. A carmine ground well covered with bold green ornament having a gold outline is, if well managed, truly gorgeous; and were the figure blue on the red ground, the lavish use of gold would render the employment of yellow unnecessary, as the slight predominance of this primary in the metal would, together with the yellow formed in the eye and cast upon the gold, satisfy all requirements.

It is a curious fact that the eye will create any colour of which there is a deficiency. This it will do, but the colour so created is of little use to the composition unless white or gold are present; if, however, there be white or gold in the composition, the colour which is absent, or is insufficiently represented, will be formed in the eye and cast upon these neutrals, and the white or the gold, as the case may be, will assume the tint of the deficient or absent colour. (See Propositions 8 and 9.)

While this occurs (and sometimes it occurs to a marked degree, as can be shown by experiment), it must not be supposed that a composition in which any element is wanting is as perfect as one which reveals no want. It is far otherwise; only Nature here comes to our assistance, and is content to help herself rather than endure our shortcomings; but in the one case we give Nature the labour of completing the harmony; while in the other, all being prepared, we receive a sense of satisfaction and repose.

In Proposition 8 we show that when blue and black are juxtaposed the black becomes "rusty," or assumes an orange tint; and in Proposition 9 we give the cause of this effect. Let a blue spot be placed on a black silk necktie, and however black the silk, it will yet appear rusty. This is a fact; but we sometimes desire to employ blue on black, and wish the black to look black, and not an orange-black. How can we do this? Obviously by substituting for the black a very dark blue, as indigo.

The bright blue spot induces orange (the complement of blue) in the eye. This orange, when cast upon black, causes the latter to look "rusty;" but if we place in the black an amount of blue sufficient to neutralise the orange cast upon it, the effect will be that of a jet black.

We have now considered those qualities of colour, and those laws of contrast and harmony, which may be said to be of the grosser sort; but we have scarcely touched on those considerations which pertain to special refinement or tenderness of effect. But let me close this part of my subject by repeating a statement already made—a statement, let me say, which first led me to perceive really harmony of colour—that *those colours, and those particular hues of colour, which improve each other to the utmost, are those which perfectly harmonise.* (Consider this statement in connection with Propositions 8, 9, 10, and 14.)

We come now to consider delicacies and refinements in colour effects, which, although dependent upon the skilful exercise of the laws enunciated, are yet of a character the power to produce which only results from the consideration of the works of the masters of great art nations; but of these effects I can say little beyond that of pointing out what should be studied.

This principle I cannot pass without notice—namely, that the finest colour effects are those of a rich, mingled, bloomy character.

Imagine a luxuriant garden, the beds in which are filled with a thousand flowers, having all the colours of the rainbow, and imagine these arranged as closely together as will permit of their growth. When viewed from a distance the effect is soft and rich, and full and varied, and is all that is pleasant. This is Nature's colouring. It is our work humbly to strive at producing like beauty with her.

This leads me to notice that primary colours (and secondary colours, also, when of great intensity) should be used chiefly in small masses, together with gold, white, or black.

Visit the Indian Museum at Whitehall,* and consider the beautiful Indian shawls and scarves and table-covers; or, if unable to do so, look in the windows of our large drapers in the chief towns, and see the true Indian fabrics,* and observe the manner in which small portions of intense reds, blues, yellows, greens, and a score of tertiary tints, are combined with white and black and gold to produce a very miracle of bloom. I know of nothing in the way of colour combination so rich, so beautiful, so gorgeous, and yet so soft, as some of these Indian shawls.

It is curious that we never find a purely Indian work otherwise than in good taste as regards colour harmony. Their works, in this respect—whether carpets, or shawls, or dress materials, or lacquered boxes, or enamelled weapons—are almost perfect—perfect in harmony, perfect in richness, perfect in the softness of their general effect. How strangely these works contrast with ours, where an harmonious work in colours is scarcely ever seen.

By the co-mingling (not co-mixing) of colours in the manner just described, a rich and bloomy effect can be got, having the general tone of a tertiary colour of any desired hue. Thus, if a wall be covered with little ornamental flowerets, by colouring all alike, and letting each contain two parts of yellow and one part of blue and one of red, the distant hue will be that of citrine: the same effect will result if the flowers are coloured variously, while the same proportions of the primaries are preserved throughout. I can conceive of no decorative effects more subtle, rich, and lovely than those of which I now speak.

Imagine three rooms, all connected by open archways, and all decorated with a thousand flower-like ornaments, and these so coloured, in this mingled manner, that in one room blue predominates, in another red, and in another yellow; we should then have a beautiful tertiary bloom in each—a subtle mingling of colour, an exquisite delicacy and refinement of treatment, a fulness such as always results from a rich mingling of hues, and an amount of detail which would interest when closely inspected; besides which, we should have the harmony of the general effect of the three rooms, the one appearing as olive, another as citrine, and the other as russet.

This mode of decoration has the advantage that it not only gives richness and beauty, but it also gives purity. If pigments are mixed together they are thereby reduced in intensity, as we have already seen; but if placed side by side, when viewed from a distance the eye will mix them, but they will suffer no diminution of brilliancy.

With the view of cultivating the eye, Eastern works cannot be too carefully studied. The Indian Museum should be the home of all those who can avail themselves of the opportunity of study which it affords; and the small Indian department of the South Kensington Museum should not be neglected, small though it is.† Chinese works must also be studied, for they likewise supply most valuable examples of colour harmony; and although they do not present such a perfect colour-bloom as do the works of India, yet they are never inharmonious, and give clearness and sharpness, together with great brilliancy, in a manner not attempted by the Indians.

The best works of Chinese embroidery are rarely seen in this country; but these are unsurpassed by the productions of any other people. For richness, splendour, and purity of colour, together with a delicious coolness, I know of nothing to equal them.

The works of the Japanese are not to be overlooked, for in certain branches of art they are inimitable, and as colourists they are almost perfect. On the commonest of their lacquer trays we generally have a bit of good colouring, and their coloured pictures are sometimes marvels of harmony.

As to the styles of colouring adopted by the nations referred to, I should say that the Indians produce rich, mingled, bloomy, *warm* effects—that is, effects in which red and yellow prevail; that the Chinese achieve clearness, repose, and *coolness*—a form

* This Museum is open free to the public.

* These will only be seen in very first-class shops.

† It may not be generally known, but nearly all our large manufacturing towns have, in connection with the chamber of commerce, a collection of Indian fabrics, filling several large volumes, which were prepared, at the expense of Government, under the superintendence of Dr. Forbes Watson, and which were given to the various towns on the condition that they be accessible to all persons who are trustworthy. Although these collections do not embrace the costly-decorated fabrics, yet much can be learned from them, and the combinations of colour are always harmonious. A much larger collection is now in course of formation.

of colouring in which blue and white prevail; and that the Japanese effects are *warm*, simple, and quiet.

Besides studying the works of India, China, and Japan, study those also of Turkey, and even those of Algeria, for here the colouring is much better than with us, although not so good as in the countries first named. No aid to progress must be neglected, and no help must be despised.

The South Kensington Museum has a very interesting collection of art-works from China and Japan; but the latter are chiefly lent. It is a strange thing that the perfect works of the East are so poorly illustrated in this national collection, while costly, yea, very costly works of inferior character, illustrative of Renaissance art, swarm as thickly as flies in August. This can only be accounted for by the fact that the heads of the institution have a feeling for pictorial rather than decorative art, and the Renaissance ornament is that which has most of the pictorial elements. To me, the style appears to owe its very weakness to this fact, for decorative art should be wholly ideal. Pictorial art is of necessity more or less imitative.

With the view of refining the judgment further in respect to colour, get a good colour-top,* and study its beautiful effects. See also the "gas tubes" illuminated by electricity, as sold in the opticians' shops, and let the prism yield you daily instruction. Soap-bubbles may also be blown, and the beautiful colours seen in them carefully noted. These and any other available means of cultivating the eye should constantly be resorted to, as by such means only can we become great colourists.

As to works on colour, we have the writings of Field, to whom we are indebted for valuable discoveries; of Hay, the decorator and friend of the late David Roberts, but some of his ideas are wild and Utopian; of Chevreul, whose work will be most useful to the student; and the small catechism of colour by Mr. Redgrave, of the South Kensington Museum, which is excellent. The student will also do well to carefully study the scientific articles on "Colour" by Professor Church in this work.

TECHNICAL DRAWING.—XV.

DRAWING FOR MACHINISTS AND ENGINEERS.

The purpose of this portion of our lessons in "Technical Drawing" is to give engineers and machinists a series of lessons in those branches of drawing which are connected with their work. The system laid down is elementary, but every endeavour has been made to render the instruction thorough, as far as it goes.

It is not long ago since the study of mechanical drawing was supposed to consist in simply copying drawings of machinery, by accurate measurement and in very fine lines. This idea has now happily exploded, but the necessity for books which should show an artisan, first, *what* he ought to learn, and then *how* to acquire such knowledge, has been deeply felt.

It is as a contribution towards the accomplishment of this purpose that the present course of lessons is put forth, in the earnest hope of aiding artisans to mount a step or two higher on the ladder of improvement.

Each part of this course of Technical lessons is, as far as possible, complete in itself; but as a knowledge of practical geometry and projection should underlie all instruction in mechanical drawing, the student is advised to read the lessons on "Practical Geometry applied to Linear Drawing" and "Projection," either prior to, or simultaneously with this; he will then be able to proceed with the advanced lessons in which the special application of those studies is shown.

Free-hand drawing of a character adapted to the wants of machinists, drawing from objects, and isometrical projection form the subjects of the various sections, and several initiatory lessons in drawing from rough sketches will be introduced, these lessons being followed with a series of drawings of modern machinery and a few simple hints on the method of colouring mechanical drawings.

These lessons have been prepared with the greatest care, and are based on the result of long and varied experience in teaching the subject. The lessons will therefore be found thoroughly practical, whilst the information given as to the history and principles of action of the different pieces of mechanism cannot fail to prove both useful and interesting to students.

We cannot close our preliminary remarks without thanking the eminent engineers and machinists who have so kindly sent us contributions of drawings and information; had the limits of our lessons permitted, we should have gladly availed ourselves of their liberality to a greater extent than it will be found we have done. Their willingness to assist in the education of workmen proves the spirit of employers towards the employed, which is one of the most glorious features of the age we live in.

MECHANICAL DRAWING GENERALLY.

The figures given in "Practical Geometry applied to Linear Drawing," and their application in "Projection," will have shown the student the importance of absolute accuracy and refinement in mechanical drawing; and as the aim of this part of our lessons is to carry the subject to a higher stage, the necessity for perfect correctness of delineation will, as the studies advance, become more and more evident.

The first lessons are therefore designed for the purpose of offering manual practice, so as to give the student, not only the power of measuring accurately, but of drawing his lines exactly where he knows they ought to be; for, strange as it may seem to some, it is not so easy to draw lines which shall pass *exactly* through required points, or which shall be absolutely parallel to each other, as might be supposed, even though the student is furnished with rule, square, and compasses. It is hoped, however, that the practice afforded by the examples given in these lessons, and the hints accompanying them, may show the learner the obstacles with which he is likely to meet, and enable him to overcome them.

We are aware that we are addressing a body of youths and men whose work is such as to cause them to be "heavy-handed," and that the hands accustomed to wield the hammer and file with such effect as to tell upon the metal which has become more practically useful than gold, will find difficulty at first in leaning so lightly on their dividers that their delicate points shall barely mark the paper, yet we have known hammermen who in their earliest lessons crushed the very points of their pencils, become with practice expert and refined draughtsmen.

We are conscious, too, that we are writing for those who have been engaged for several hours in severe toil, whose occupation has not admitted of its being exercised in the open air, or even in airy apartments, as might be the case in many other walks of industry, but whose labour has been carried on for the most part in necessarily heated workshops, under the lurid glare of the forge-fire, amid the din of steam-hammers, and the thousand other noises inseparable from mechanical works.

It might be thought that from men so situated a sacrifice is demanded when they are urged to attend evening classes, or even to pursue home study when their day's work is over. We do not think so. We cannot believe that any man's work is really done, until he has made an effort, however small, to develop those mental powers with which he has been so mercifully endowed; and he will find, too, that the effect of the information he gains will not be confined to the evenings, but that the knowledge he acquires will increase his interest in the form and action of the machines amongst which he is engaged, and his work will not only be done better, but with greater pleasure than before.

The experience of many years has shown us that men who are desirous of working as intelligent beings, attend the evening classes with the greatest regularity, often bringing their sons to share the instruction given; and that many hours are spent at home in working out the lessons which have been received. In such practice these lessons will be found especially useful, and therefore practical hints are given so that the student may not be delayed by not knowing "how to go on."

Fig. 165 represents a drawing-board with T-square and set-square. The T-square should only be used for lines in one direction; for, unless the board be one which has recently been squared, it cannot be depended upon, and the lines drawn by means of the T-square, when guided by different sides of the board, will not generally be found to be at right angles to each other.

* Not the so-called colour or chameleon top sold in the shops during the past winter, but the more scientific toy procurable of opticians, together with the perforated discs of Mr. John Graham, M.R.C.S., of Tunbridge, Kent. See also THE POPULAR EDUCATOR, "Recreative Science"—XX. (Vol. VI., p. 231).

Although a few plain hints on linear drawing, and a plain description of some of the mathematical instruments mostly used, have been given in our lessons on "Technical Drawing," some few of the remarks there given are repeated here to avoid the trouble of reference, together with such additions as the subject of these lessons renders necessary.

The best T-squares are those which have the blade screwed *across* the stock, which form (see Fig. 165) admits of the set-square being moved freely along, in order to draw a line near the edge of the paper, whilst it would be obstructed by the stock if the blade were mortised into it.

It is important that the set-square should be *true* whichever way it may be worked, and this may be tested by drawing a line against its edge when placed as at A (Fig. 165), and then turning it over as at B, bring its edge up to the line drawn; then if another drawn against the edge in its present position agrees perfectly with the former one, the square is true; if not, it will require setting.

Any working man or student will, with a little care, be able to do this for himself, by placing a sheet of very fine sand-paper on a *perfectly* flat surface, and rubbing the edge of the set-square against it, keeping the square upright, and pressing a little heavier on the part which requires "easing" than on the other.

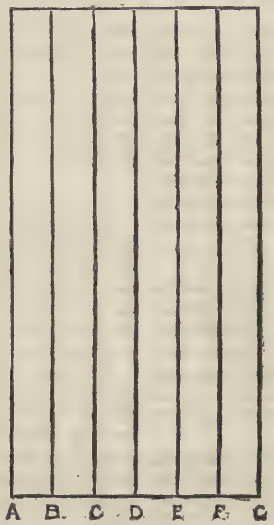


Fig. 166.

It may be well, whilst speaking of this portion of the subject, to advise you to rub off the angles of the edges of your square. We do not mean that you should actually *bevel* them, but merely rub off enough of the sharp edge to raise it almost imperceptibly above the paper, when the square is lying flat; and we recommend you to do this to *all* the edges, for a purpose of which we will tell you presently.

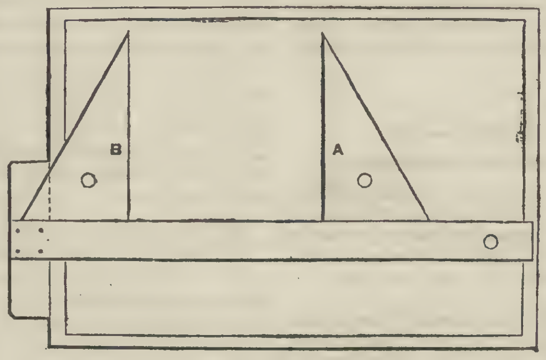


Fig. 165.

The T-square, then, being worked against the left-hand edge of the drawing-board, will give all the horizontal lines, and can be moved higher or lower without laying down the pencil or inking-pen. The lines perpendicular to the others are drawn by means of the set-square, as shown in Fig. 165. Should it be required to lengthen the line, it is only necessary to move the T-square downwards, keeping the set-square in its place against it. If these instructions are carefully followed, lines at right angles to each other will be ensured.

In pencilling your work you will, as a general rule, find an HB pencil the best for the larger parts, and an H for the teeth of wheels and more minute portions. Be careful not to press too heavily on your pencil; the lines should be so lightly done that they can, if required, be easily rubbed out with india-rubber, without disturbing the grain on the surface of the paper.

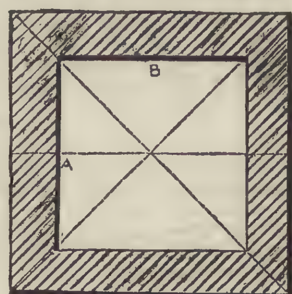


Fig. 169.

Remember that, as a rule, mechanical drawings are not left in pencil, but that the pencil-lines are merely drawn as guides for inking. Therefore as little lead as possible should be deposited on the paper; for as the nibs of the inking-pen are drawn over the lines they gather up the grit of the lead, which lodges between them, causing the line to become thick and irregular. When, therefore, the work is finished in pencil, it is advisable to pass the india-rubber lightly over the surface, by this means removing the loose particles of lead without erasing the lines.

Draw all pencil-lines past each other at right angles and intersections; for as the edge of the rule partly obstructs your view of the line when inking, you are liable to pass over the required point, which annoyance will be prevented by another pencil-line crossing at the exact spot at which you are to stop. If you have by mistake drawn a line too long, do not scratch out the superfluous length until after you have coloured, as the roughened surface will cause the colour to run. For rubbing out an ink-line, if not too thick, you will find ink-eraser, or very fine glass-paper (No. 1), better than the knife, as it removes the surface of the paper more equally.

Never use writing-ink in your mathematical instruments. Indian ink is sold in sticks, which may be purchased at from twopence to a shilling each. This should be rubbed in a small saucer, or slab, with a little water. You should put some in your pen to try on a slip of paper, in order that you may know if it is dark enough before you begin to work with it. A little indigo rubbed with the Indian ink darkens it, and removes the brown tinge.

Drawing-boards of various kinds are sold; some are framed, some clamped, and some rabbeted. The different methods are all so many plans to secure the board against twisting and cracking; and yet all of them, however ingenious, fail, if the wood is not well seasoned before the board is made up; so that we advise you, if you are about having a drawing-board made, not to attend so much to the *make* as to the *stuff* it is made of. Most machinists who are connected with large works will have seen something of woodwork, and the carpenters with whom they may be associated will, no doubt, give them the benefit of their assistance in the matter.

To persons not so situated we suggest, that it is safer to *buy* a ready-made board, from a stock which has been some time in hand. They will then have an opportunity of selecting such as are in some degree seasoned.

For drawings such as the elementary studies in these lessons, or simple geometrical figures which are soon finished, it will be sufficient to fasten the paper down by means of drawing-pins, which may be bought at one halfpenny each; but if the drawing is likely to take some time, or is to be coloured, it is best to "stretch" the paper. This is done as follows:—Cut the sheet to a trifle smaller than your board, and turn up a margin about half an inch broad all round; then lay the paper face downwards, and spread water over the surface (the back of the sheet) with a sponge; allow the water to soak in for a minute or two, but keep the surface equally moist all over; raise the paper by its edges, turn it over, so that the wet side may rest on the board, and apply strong paste to the turned-up edges; rub these down, and in doing so draw the paper outward. It is a good plan to burnish the margin well with the handle of your penknife, by which means you press the air out, and make sure that the paper is properly pasted down. The board must then be placed horizontally to dry. If, when nearly dry, one or two large blisters remain which do not seem to decrease, prick a small hole or two in them with a needle to let out the air, which will, in most cases, remedy the evil; if not, pass the sponge over the whole face of the paper, moistening it especially towards the outer part. It is advisable to operate upon a small sheet at first, until the "knack" of stretching is acquired.

The size of the paper most generally used by students is called "imperial." This has been fixed as the size for the competitive drawings sent to the Government Department of

Science and Art, and is found the most convenient for general purposes. It is, therefore, advisable to have your drawing-board made of the same size as the paper, thus avoiding waste. The whole sheet is 30 in. × 22 in. You will find it enough for the present to use the *half* sheet, the size of which will be 22 in. × 15 in. Your board should be a trifle larger all round.

Be careful that you incline your pencil so that its *point* is guided by the set-square all along; otherwise your lines will not be upright.

When properly pencilled, dust off the lead on the surface with india-rubber, and then ink your work as already directed.

Hold your draw-pen as upright as possible, leaning your first

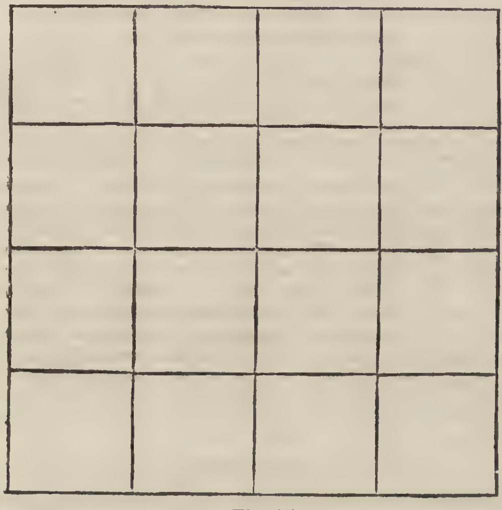


Fig. 167.

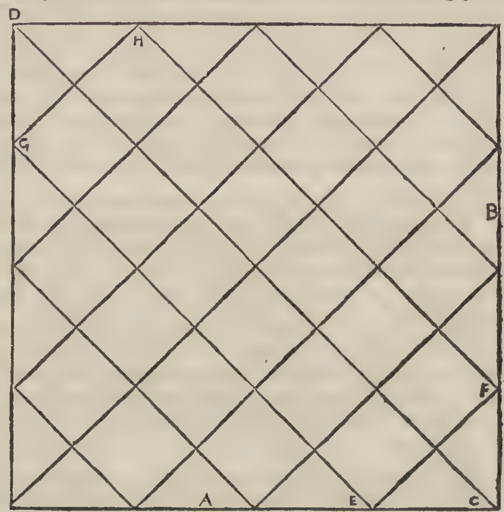


Fig. 168.

LINEAR DRAWING BY MEANS OF INSTRUMENTS.

Fig. 166.—The object in this lesson is to give practice in ruling straight lines at equal distances apart, and of the same length and thickness.

Draw a light line at the top and another at the bottom. These lines are to be ruled by the aid of the T-square, worked against the left-hand edge of the drawing-board.

Take the distance between the lines A B in your dividers, and

finger on the head of the screw. If you slant the pen only one of its nibs will touch the paper, then the edge of your line will be ragged.

Before inking, rule a few lines on another piece of paper to try if your draw-pen is as open as is required to give the proper thickness of line, or if the ink is of the right colour, etc. You will find this little precaution will sometimes prevent great annoyance, and often save a drawing from being spoiled.

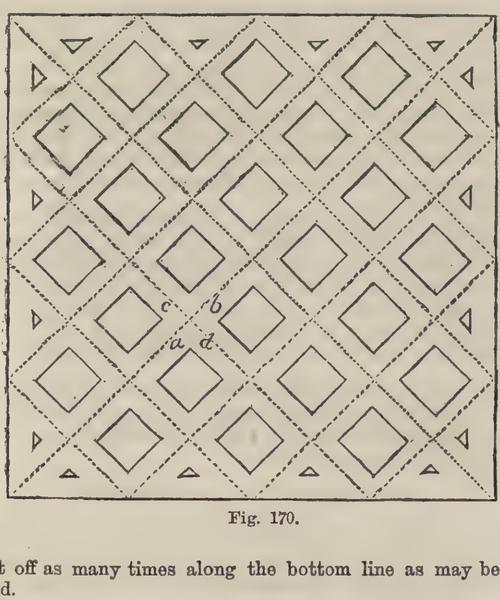


Fig. 170.

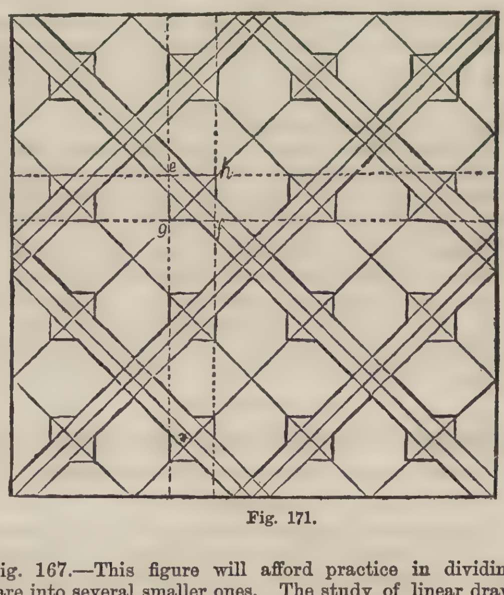


Fig. 171.

set it off as many times along the bottom line as may be required.

(The dividers are the smaller-sized compasses without the pencil or pen legs. If you have not one of these, you must use your compass, taking care to insert the steel leg instead of that which holds a pencil.)

Having, then, set off from A the lengths B, C, D, E, F, G, keep the blade of your T-square horizontal, but moved a trifle lower down. Place your set-square against it, as shown in Fig. 165, and draw perpendiculars from the points marked.

Fig. 167.—This figure will afford practice in dividing a square into several smaller ones. The study of linear drawing will have shown the geometrical method of constructing the original figure and of dividing lines; it is therefore only necessary here to advise you in drawing the square in pencil to carry the sides *beyond* the angles, which enables you when inking, and your rule covers the figure, to know the exact point at which to stop. This is important, for if you do not draw your ink-line quite long enough, you will have the trouble of "piecing" it, which is always difficult, but especially so if the line be fine;

and if too long, you will have to erase the superfluous length, which causes annoyance and trouble, and in doing which the angle of the square is often damaged.

Fig. 168 is an exercise in the accurate use of the set-square of 45°.

Having drawn the base (A), and one other side of the square (as B) at right angles to it, place the set-square of 45° so that its hypothenuse* may enter the right angle C; draw the line which will subsequently become one of the diagonals. Now from the extremities of the two sides of the square draw lines for the other two sides, and these should meet at D, *on the line* C. If this is not the case, the lines are not at right angles to each other, or there is some other inaccuracy, and you had better rub your work out, to avoid being compelled to do so when further advanced.

Having now drawn the square and one diagonal, draw the other. This must also be done with the set-square, for if your figure be accurate, the set-square placed against the one angle should give a line direct to the other. Divide the base into the required number of equal parts, and moving the set-square along the T-square, draw the lines across in each direction.

The utmost care is necessary in doing this, for it must be pointed out that it is only required to mark the division on the base, since the lines drawn from these should give the points in the sides. Thus the line drawn from E will give the point G, and if the work be correctly done the hypothenuse of the set-square when reversed should give F H and the other lines parallel to it.

Fig. 169 shows the mode of drawing lines to indicate that the drawing represents a section or cutting, and is another example of the use of the set-square, these lines being drawn at 45°. Care is necessary in keeping them all the same distance apart, and of the same thickness. The lines which on the right-hand side are thicker than those on the left are called *shade lines.* They indicate that a square *open* tube is represented, and that the light is proceeding from the left side. If it were intended to show that the walls of the tube are cut through, and that the space they enclose is filled up by a flat board not cut through, the lines A and B would be drawn of the same thickness as the other two.

Fig. 170 is an application of Fig. 168, and represents an iron grating. To draw this figure, proceed as in Fig. 168, working all the crossing lines in dots or very finely. On each side of the intersections set off half the width of the bars, as shown at *a*, *b*, *c*, *d*, and through these points, by means of the set-square, draw the necessary lines, all of which must be parallel to those previously drawn. The rest of the subject will now be easily completed without further instructions.

Fig. 171 is another application of the same study. Having drawn the original fine lines crossing the square, set off half the thickness of the bars as shown at *a*, *b*, *c*, *d* in the previous figure. From the same points mark off the semi-diagonal of the square which is to be drawn at each intersection—viz., *e*, *f*, *g*, *h*. It will be seen that one square will guide those of two lines at right angles to each other; thus *e h* and *g f* produced will give the horizontal lines of all the squares on the same line, whilst *e g* and *h f* will give the perpendiculars of all the squares above and below the square *e g f h*. If this plan be pursued, instead of measuring each square separately, much time will be saved.

ANIMAL COMMERCIAL PRODUCTS.—X.

PRODUCTS OF THE CLASS AVES (*continued*).

BED-FEATHERS.

THE lower barbs in feathers are usually loose, and form the down, which is called the "accessory plume." The quantity of this down varies in different species of birds, and even in the feathers taken from different portions of the body of the same bird. It is most abundant on aquatic birds, and as the value of bed-feathers depends on its amount, the feathers of ducks, swans, and geese—which have the "accessory plume" nearly as large as the feather—are the most esteemed.

The qualities sought for in bed-feathers—softness, elasticity, lightness, and warmth—are combined in common goose feathers; they are considered best when plucked from the living bird, and this cruel operation is repeated from three to five times in a year. Young birds are plucked as well as those of mature growth—the early plucking being supposed to favour the growth of the feathers. The less valuable kinds of feathers, obtained from turkeys, ducks, and fowls, are also used for bed-stuffing, and are called "poultry feathers."

Eider Duck (*Anas mollissima*).—This bird furnishes the softest, finest, and most valuable down-feathers that are in the market. Eider-down is procured from the nest of this bird, which robs its own breast of feathers in order to make a warm home for its young. The eider ducks build their nests in great numbers, in almost inaccessible rocky situations on the coasts of Ireland, Scotland, the Faroe Islands, Lapland, Nova Zembla, and Spitzbergen; and these nests are, at great risk of life, annually plundered of their down by the fowlers. Eider-down comes to this country in the form of balls, about the size of a man's fist, and weighing three or four pounds. It is so fine and soft, that if one of these balls is spread and warmed over hot coals, it will expand and fill a bed big enough for two persons. Eider-down is only used as a covering for beds, and never should be slept upon, as it thereby loses its elasticity.

In 1864 our imports of bed-feathers from Russia, Hamburg, France, and other parts of the Continent, amounted to 8,786 cwt., valued at £76,488; white ostrich feathers, 16,192 lb., valued at £113,480; black ostrich feathers, 26,643 lb., valued at £80,583; and feathers of all other kinds, 24,186 lb., valued at £11,485.

QUILL PENS.

The earliest pens, such as were used for writing on papyrus with a fluid ink, were made of reeds. Reed pens are still in use in Arabia, as they suit the Arabic character better than quill pens. These reeds are collected near the shores of the Persian Gulf, whence they are sent to various parts of the East. Quill pens are chiefly supplied by the goose, swan, and crow—the ostrich, turkey, and other birds occasionally contributing. Crow quills are usually employed in fine drawings, on account of the fine point to which they can be brought. Goose quills are employed for ordinary writing; but swan and turkey quills, being larger, are preferable for copying.

Two principal sorts of quills are known in commerce—viz., Dutch quills, which are transparent and glass-like; and Hamburg quills, which are milk-white and clouded. Dutch quills are much esteemed; the Dutch were the first to find out the art of preparing quills for market, by removing the oil which impregnates them, and prevents the ink from flowing freely along the pen. Quills are obtained in the greatest quantities from the countries along the Baltic; Hamburg is still the principal place for preparing and exporting them. Next to the Hamburg and Dutch quills, those of Riga are much liked, especially in England.

The manufacture of steel pens does not appear to have diminished the demand for quills. In 1855 we imported, independently of our home supply, 26,500,000 goose and swan quills. The quills used are the five outer feathers of the wing, which are classified according to the order in which they are fixed in the wing, the second and third being the best. With proper management, a goose may afford twenty quills during the year.

In the fens of Lincolnshire, geese are kept in large numbers. During the breeding season they are lodged around the owner's house. A gooseherd, it is said, can distinguish every goose in the flock by the tones of its voice.

PRODUCTS OF THE CLASS REPTILIA.

Reptilia (Latin, *reptilia*, from *repto*, I creep).—Cold-blooded, vertebrated animals, having a heart so constructed as to transmit only a portion of the blood to the lungs. The blood is therefore imperfectly oxygenated, and there is a lower degree of animal heat. The amount of venous blood, however, transmitted to the general system varies in the different reptiles, and in proportion as there is less or more of it, is there a corresponding difference in their temperature and vital activity.

As reptiles have no need of preserving a temperature many degrees warmer than that of the medium in which they live, they are covered with scales, or hard bony plates, and without the warm clothing of the birds and mammalia.

* *Hypothenuse.* The longest side of a right-angled triangle.

The class Reptilia is divided into four orders, viz.:—

1. *Chelonia* (Greek, *chelone*, a tortoise), which are characterised by the enclosure of the body in a double shield or shell, out of which extend the head, tail, and four extremities. Examples: tortoise and turtle.

2. *Lacertilia*, or *Sauria* (lizards), having the body and tail elongated, the jaws furnished with teeth, the skin covered with scales, and the feet generally four in number. Examples: green lizard and blind-worm.

3. *Crocodilia* include the alligators of America, the true crocodiles of Africa, and the gavials of Asia. Gigantic lizards, covered with closely-set bony plates.

4. *Ophidia* (Greek, *ophis*, a serpent), which are distinguished by the absence of the extremities, as in the snake.

The Chelonia are commercially the most valuable of the above orders, as we derive from them two important articles—turtle soup and tortoise-shell—the former the greatest luxury of the table, and the latter the most prized of horny materials.

Green Turtle (*Chelonia mydas*).—This is one of the largest of the genus, often measuring five feet in length, and weighing between 500 and 600 pounds. It receives its name from the green colour of its fat. Its flesh is much esteemed, and in this country it is regarded as a great luxury, large quantities being continually imported for the supply of the London taverns alone. Green turtles are met with in the Atlantic Ocean, where they are widely distributed. They are found in great abundance near the Bahama Islands, and when they come ashore to deposit their eggs in holes in the sand are usually caught, either by harpooning or by turning them over on their backs, for when once turned they cannot get on their feet again. The Chinese catch them with the sucking-fish (*Remora*), which is put into the water with a string tied to its tail. The remora darts at the turtle, to which it firmly adheres by means of its sucking apparatus, and both fish and turtle are then drawn into the boat.

Mr. Darwin thus describes the capture of this turtle at Keeling's Island: "The water is so clear and shallow that at first a turtle quickly dives out of sight; yet, in a canoe or boat under sail, the pursuers, after no very long chase, come up to it. A man standing ready in the bows at this moment dashes through the water upon the turtle's back; then, clinging with both hands by the shell of the neck, he is carried away until the animal becomes exhausted and is secured. It was quite an interesting chase to see the animals thus doubling about, and the men dashing into the water trying to seize their prey."

Hawk's-Bill Turtle (*Chelonia imbricata*).—The horn-like plates of this animal, and also of the carett, or giant tortoise (*Testudo caretta*), which lives in all the seas of the torrid zone, furnish the tortoise-shell of commerce. The island of Ascension is a place of resort for these reptiles, and thousands of them are annually destroyed there. In most species of tortoise the scales which compose the carapace or upper covering adhere to each other by their edges, like inlaid work; but in the hawk's-bill turtle these scales are imbricated, or overlap one another, like the tiles on the roof of a house. The head is also smaller than in the other tortoises; but the neck is longer, and the beak narrower, sharper, and more curved, resembling a hawk's bill. The lamellæ, or plates of the shell, are semi-transparent, and variegated with whitish, yellowish, reddish, and dark-brown clouds and undulations, so as to constitute, when properly prepared and polished, an elegant article for ornamental purposes. The shell of this animal is therefore largely imported into this country, as much as thirty tons' weight being annually consumed by the manufacturers. Tortoise-shell is used for the handles of penknives and razors, spectacle-frames, card-cases, ladies' side, back, and dressing combs, and for inlaying work-boxes. The best tortoise-shell comes from the Indian Archipelago, where Singapore is the principal port for its exportation. It is also sent from the West Indies; from the Gallapagos Islands, situated on the west coast of South America; and from the Mauritius, Cape Verde, and Canary Islands.

"A large number of turtle eggs are secured every year for the sake of turtle oil. The eggs, when collected, are thrown into long troughs of water, and being broken and stirred with shovels, they remain exposed to the sun till the yolk, the oily part, is collected on the surface, and removed and boiled over a quick fire. This animal oil, or 'turtle grease,' is limpid, inodorous, and scarcely yellow; and it is used not merely to burn in lamps, but in dressing victuals, to which it imparts no disagreeable taste. The total gathering from the shores between the junction of the Orinoco and Apure is 5,000 jars, and it takes about 5,000 eggs to furnish one jar of oil."*

PRODUCTS OF THE CLASS AMPHIBIA.

Rana esculenta (edible frog).—This species is eaten in France.

Rana pipiens (American bull-frog).—The hind limbs are considered a great luxury, and are exposed for sale in the markets of the United States.

Siredon pisciforme (the axolotl).—Inhabits the lake near the city of Mexico, where it is very abundant, attaining a length of from ten to fifteen inches. Thousands are sold, and esteemed a great delicacy by the Mexicans.

PRODUCTS OF THE CLASS PISCES.

Vertebrate animals inhabiting water, breathing by means of branchiæ or gills—vascular organs into which the circulating fluid enters, and which is submitted in a state of minute subdivision in the vessels of the gills to the air contained in the water, and so oxygenated—swimming by means of flattened expanded organs called fins, the entire body being mostly covered with cartilaginous scales. The specific gravity of fishes is nearly the same as that of the watery element in which they live. Most of them have a membranous bag at the lower side of the spinal column, known as the "air-bladder," which is so organised that the fish can vary its specific gravity by contracting or expanding the bladder, expelling the air or taking it in, and so sink or rise in the water at pleasure. It is somewhat remarkable that this air-bladder is quite rudimentary or altogether absent in fishes which live much at the bottom of the water, seldom or never coming to the surface, such as plaice, turbot, and sole. Progression in any direction is effected by the movements of the tail. The craving for food seems to be that which gives the chief impulse to their movements. Their rapacity has no bounds whatever; even when taken out of the water, and just expiring, they will greedily swallow the very bait which lured them to destruction.

The class of fishes has been sub-divided by Cuvier into two sub-classes.

1. *Pisces ossei*, or bony fishes, comprising those which have a true bony skeleton. Examples: herrings, salmon, and cod.

2. *Pisces cartilaginei*, or cartilaginous fishes, including those in which the skeleton never passes beyond its primitive condition of gristle or cartilage. Examples: the sturgeon, ray, and shark.

PROJECTION.—X.

PENETRATIONS OF SOLIDS (*continued*).

PROJECTION OF BUILDINGS.

It is now necessary to develop the larger cylinder, and to draw accurately upon the development the form of the aperture through which the smaller one shall pass. Now it must be borne in mind that this aperture, notwithstanding that it is to contain a cylinder, will not be a circle when the surface through which it is pierced is laid out flat.

This will be evident on referring to the plan in Fig. 109 (page 205), where the length of the straight line e to e' is the *real* width of the penetrating cylinder; whereas the distance between e and e', when measured on the circumference of the plan, would be much more; but as the axes of the two cylinders penetrate each other at right angles, the diameter in the elevation will remain unaltered.

The development of the general form of the cylinder will be accomplished by the method shown in Fig. 84† (page 101).

On this development (Fig. 111) draw a centre line A° representing A in the plan. The outer perpendiculars B' B'' will represent B in the plan. On each side of A° set off the lengths $g\,f\,e$, and erect perpendiculars; then the heights of the points

* See Bates' "Naturalist on the Amazon."

† The difference between this distance on the curve and on a straight line would be considerable, therefore divide it into several parts, x, x, x, and set them off separately, by which means the difference will be lessened.

correspondingly lettered in the elevation, marked off on these perpendiculars, will give points through which the development of the aperture may be traced.

It now only remains to develop the form of one of the ends of the penetrating or smaller cylinder. To do this, draw a horizontal line (Fig. 112), and about the middle at E erect a perpendicular. On each side of E set off the distances *f*, *g*, *c*, *g*, *f*, E, into which the end of the smaller cylinder is divided, and from these points erect perpendiculars. On these set off the lengths of the lines between E E (Fig. 109) and the plan of the larger cylinder—viz., E *e*, F *f*, G *g*, C′ B, etc. The curve uniting the extremities of these perpendiculars will give the form in which the piece of metal is to be cut, so that when rolled and joined at its outer edges, it may form a part of a cylinder of the required size which will exactly fit to the aperture in the larger cylinder already explained.

TO DRAW A CONE PENETRATED BY A CYLINDER, THEIR AXES BEING AT RIGHT ANGLES TO EACH OTHER (Fig. 113).

Draw in the first place the mere elevation of the cone, A B C, and of the cylinder, D D′ E E′, intersecting each other in F F′ G G′; from these the general plan may be projected in the horizontal plane. The next problem for solution is the curve line may be followed throughout) the same lettering is given —namely, *d′ b′ c′*. From these points carry perpendiculars cutting the base line of the elevation of the cone in *d′ b′ c′*, and draw lines from these points to the apex, C, of the cone. Intersect these lines by others drawn from *b c d* in the original semicircle, and through the points thus obtained the curve of penetration, starting at F and G, and ending in F and G′, is to be drawn. It is now necessary to show on the plan the curve formed at the junction or penetration of the two bodies. Four points in these curves may at once be found by dropping perpendiculars from F, F′ and G, G′ in the elevation to cut X X in F, F′ and G, G′. Now it will be remembered that every horizontal section of a right cone is a circle, and thus the lines parallel to the base on which the points *b*, *c*, *d* exist, are really edge elevations of circles, the diameter of which is regulated by their position on the cone. The length from point 1′ on the edge of the cone to 1 in the axis is thus the radius of the circle on which the point *b*, and the corresponding point beyond it, are placed. Therefore, with this radius describe a circle from the centre of the plan, and drop a perpendicular from *b*, cutting it in *b b*. Draw a circle from the same centre of the plan with radius 2 2′, and a perpendicular from *c*, cutting it in *c c*. Draw a circle from the same centre with radius 3 3′, and

Fig. 111.

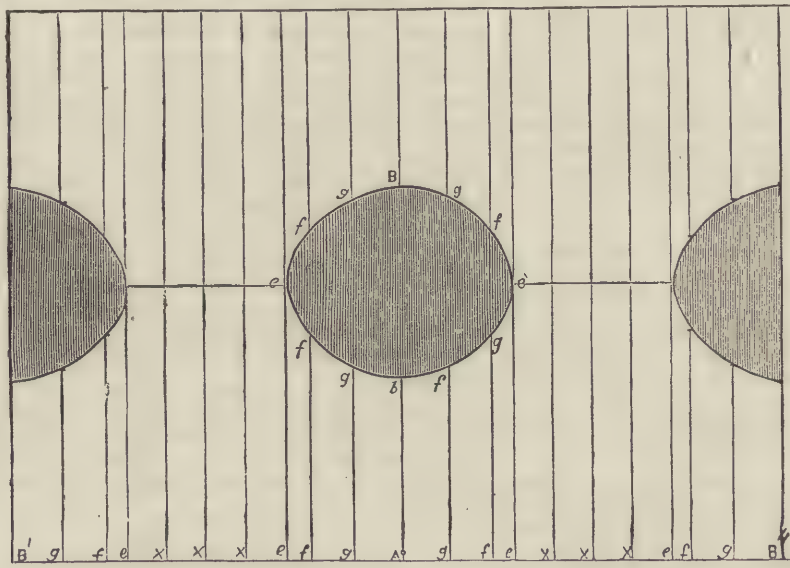
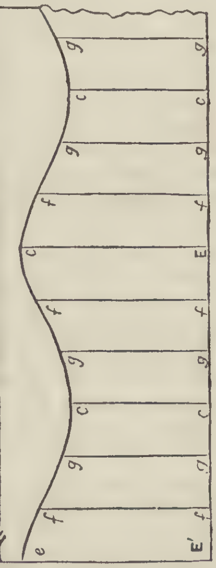


Fig. 112.



which will be generated by the intersection of the cylinder (which is a round body of *equal* diameter) with the cone (which is a round body of ever decreasing diameter). At D D′ draw the perpendicular H I equal to the altitude of the cone, and from J, the middle line of the elevation of the cylinder, describe a semicircle equal to half the end of the cylinder. From I draw a line touching this semicircle in *c*, and reaching the intersecting line in *c′*. Between D and *c* and *c* and D′ mark off any number of divisions, as *b*, *d*, etc. It must, of course, be understood that the greater the number of divisions marked off, the greater will be the number of points subsequently obtained, and, of course, the greater the accuracy of the intersecting curve and development; but the object of the author is to make the operations as clear as possible, and therefore, in order to avoid one set of lines passing over another, and causing difficulties and confusion, he has only marked one division (*b*) in the upper and one (*d*) in the lower portion of the elevation. The student, who is expected to work this figure to a much larger scale, will, however, do wisely to use many more points, all of which are worked in the same manner. From I draw a line through *b* cutting the intersecting line in *b′*, and from I draw a line through *d* cutting the intersecting line in *d′*. Through the centre of the plan draw the line X X, and carry perpendiculars to it from *c′ b′ d′*; and from D′, with radius D *d*, D *b*, D *c*, draw arcs cutting I H produced in points similarly lettered.

From these points draw lines parallel to X X, cutting the plan of the cone in points to which (in order that the same a perpendicular from *d*, cutting it in *d d*. Draw the curve F *d c b* F′ *d c b*, which will be the plan of the aperture required. (Of course the corresponding lines on the other side will give a similar result.)

TO PROJECT A SMALL CHURCH FROM THE PLAN (Fig. 114).

The church, it will be seen, is made up entirely of simple solids—viz., square prisms of various lengths, triangular prisms, and a square pyramid; and as the student has already had some practice in these, he will find, it is believed, but little (if any) difficulty in following out the instructions, although the diagram is not lettered.

The building is to be considered in the first instance formed of the square prisms only—that is, divested of the triangular prisms which form the roof, and also of the pyramid which forms the spire.

These solids, then, will be represented in the plan by two rectangles crossing each other at right angles, and as they are equal in width their intersection is a *square*, which is the plan of the tower; the shorter end of the longer rectangle then becomes the plan of the chancel, and the longer end the plan of the nave; the smaller rectangles form the plans of the transepts. It is advisable now to proceed with the projection of the body of the church from the plan. This operation is very simple, requiring only that perpendiculars should be drawn from the various points. From the two front angles of the transept which faces the spectator, therefore, draw perpen-

diculars, and a horizontal line cutting them off at a height above the intersecting line equal to the required height of the walls of the church. This horizontal line may be drawn of indefinite length, as it will regulate the height of the whole body of the building. A perpendicular drawn from the third angle of the transept (*i.e.*, the front left-hand corner of the square) will give the one edge of the tower of which the square is the plan, and a perpendicular drawn from the right-hand corner of the square will give, not only the side of the transept, but will, if continued, give the right-hand line of the front of the tower: further, a perpendicular raised from the distant right-hand corner of the square will give the side, the height of which may be determined by a horizontal to form the top line of the walls of the tower.

Next draw perpendiculars from the two angles of the right-hand end of the longer rectangle, and these carried up will give the projection of the rectangle, or wall forming the extreme end of the nave.

We now return to the plan, and draw the diagonals, which constitute the plan of the edges of the pyramidical spire. From their intersection draw a perpendicular, and on this mark the height of the required pyramid, this line being the axis. From the apex thus fixed draw lines to the upper angles of the projection of the tower, which will complete the spire.

Again reverting to the plan, draw lines through the middle of the rectangles, which will give the plans of the ridges of the roof (Fig. 48, page 73). From the point where the ridge-line meets the front of the transept draw a perpendicular, and mark on this, above the top line of the walls, the *perpendicular* height shown in the dotted triangle annexed. Join this point to the upper corners of the front of the transept, and this will complete its gable. From the apex of this triangle draw a horizontal line, and intersect it by a perpendicular drawn from the point where the ridge-line in the plan cuts the front line of the square. This intersection will give the point where the ridge meets the front of the tower. From this point draw a line parallel to that side of the triangle, and this will complete the visible transept; the opposite one is, of course, hidden by the body of the church, and could not therefore be seen in the present view. The student is, however, advised to project this object on the inclined plane, as shown in Lesson IV. (page 72), when the upper portion at least of the hidden transept will be seen. The rectangular part of the wall at the end of the nave has already been projected from the plan, and it now only remains to complete it by the addition of the gable.

It must be obvious that the gable-point will be immediately over the point where the ridge-line meets the end of the nave in the plan; and therefore from this point erect a perpendicular, and carry it up between the two lines which represent the edges of the end of the nave. Draw a perpendicular, too, from the point where the ridge-line cuts the plan of the tower. A horizontal drawn from the gable-point of the transept will cut these perpendiculars, and give the corresponding point in the end of the nave, and in the part of the roof which meets the side of the tower. Produce this horizontal until it meets a perpendicular drawn from the end of the ridge of the chancel in the plan, and this will give the distant point in the ridge, and thus complete the projection of the church.

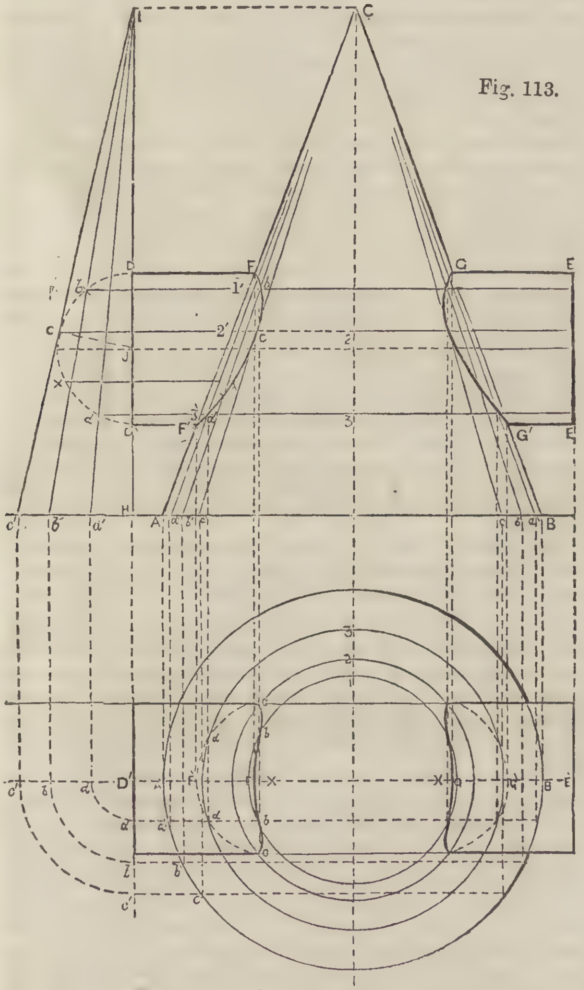


Fig. 113.

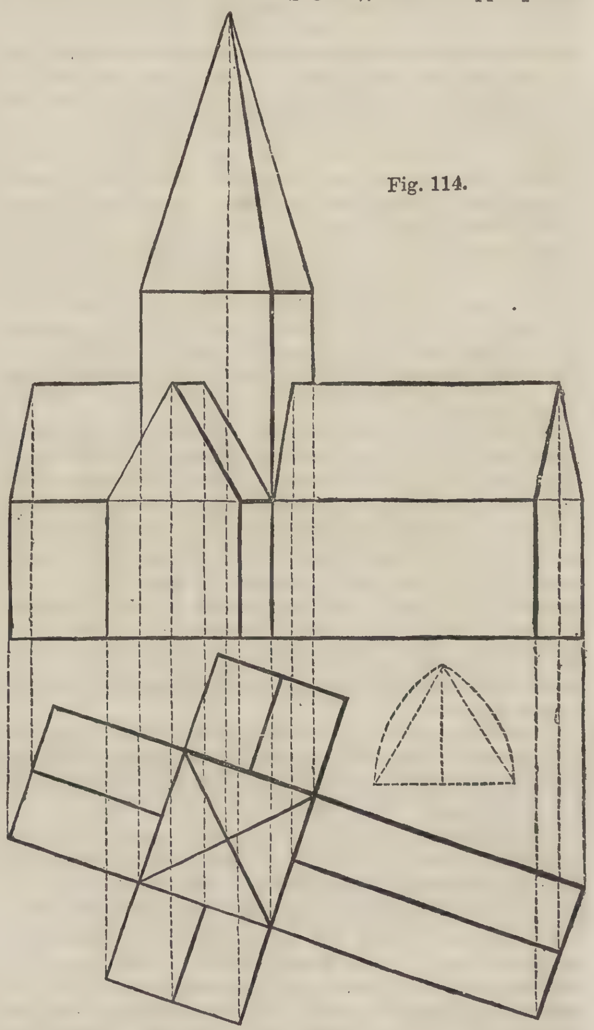


Fig. 114.

AGRICULTURAL CHEMISTRY.—V.

BY CHARLES A. CAMERON, M.D., PH.D.,
Professor of Hygiene in the Royal College of Surgeons, Ireland, etc.

CHAPTER V.—INFLUENCE OF CULTIVATION AND DRAINAGE UPON SOILS.

WHEN crops are grown in a rich field year after year without any manure being applied to it, its soil soon ceases to be very productive. It was formerly the general opinion amongst agriculturists, and even amongst agricultural chemists, that unmanured land, if heavily cropped, would soon become perfectly infertile, or barren; but the accurately conducted investigations of Mr. J. B. Lawes, of Rothamstead, and the prolonged experiment of the late Mr. Smith, of Lois Weedon, prove that it is not in man's power to reduce fertile soils to a condition of absolute sterility. Indeed, it would appear that no system of husbandry, however improvident, is capable of permanently deteriorating the productive powers of the earth.

Mr. J. B. Lawes and the Rev. Mr. Smith have grown crops year after year for a long period in the same field, without the use of any kind of manure. Nor were the crops obtained very inferior either with regard to quantity or quality. Under ordinary circumstances, however, it is found expedient to restore to the soil, wholly or partly, in the form of manure, the mineral substances removed from it by crops. Tillage, or cultivation, is to a great extent a substitute for manure; and the less fertilising matter applied to the soil, the greater is the necessity for its thorough mechanical treatment. The quantity of fertilising matter present in most soils is practically inexhaustible; but only a minute proportion of it exists in a condition in which it can immediately contribute to the nourishment of plants.

We have already shown that calcic phosphate is essential to plants, and that it is an abundant ingredient of their ashes. Now every soil capable of growing vegetables contains this substance, but chiefly as an ingredient of stones and coarse particles, upon which plants cannot feed. Any one who examines a specimen of clay will see how very little of it is in the state of even coarse powder. It is the very finest powder contained in the soil which supplies the great bulk of the mineral food of plants; hence any process by which the coarse lumps and particles are pulverised increases the productiveness of the land. It was only by means of thorough cultivation that Mr. Lawes and the Rev. Mr. Smith succeeded in growing crop after crop of wheat in succession, in the same field, and without the use of manure.

It would appear that the most exhaustive system of cropping may soon put land out of *condition*, but cannot affect its fertility. In practice, poor and inferior lands always remain so, whilst a rich soil can only for a brief time be reduced to an inferior condition. If, as Mr. Lawes truly observes, it were possible by any system of cropping to abstract all, or even the greater portion, of the elements of fertility from the ground, there would not now be a fertile field in these countries. Needy landlords and poor tenants would long since have taken everything worth abstracting from the fields of these islands.

A good piece of land, well manured and sufficiently tilled, produces so many bushels of corn per acre. If the manure be discontinued, and the amount of tillage not augmented, an immediate and large decrease in the productiveness of the land results, and in two or three years it goes out of condition. The yield does not, however, continue to decrease, for after a short time it remains stationary for an indefinite period.

The amounts of potash, phosphoric acid, and other of the mineral elements of the food of plants are so very large in loams and clays, that it would require centuries of cropping to wholly exhaust them. They are, however, bound up in the rocky portion of the soil, and only a minute proportion of them is annually set free. It is a wise arrangement of Providence that phosphoric acid and potash should be locked up in the soil, and even that the earth should contain such small proportions of these substances. Were it otherwise—were potash, phosphoric acid, and the other ash ingredients of plants supplied in an available form, and in unlimited quantities—the husbandman could not earn his bread by the sweat of his brow, in obedience to the wise fiat of the First Great Cause. It is not a mere accident that the minerals which are least abundant in the soil are the most abundant in plants.

In very light soils, particularly those derived from the disintegration of limestones, the system of tillage without manure could not be carried on for more than a few years, without reducing the yield to an extent that would be altogether unremunerative. On the rich loams and stiff clays, which usually are very rich in potash and phosphoric acid, thorough cultivation will, without the aid of manure, produce average crops for perhaps more than a century. The maximum of productiveness is, however, attained when the land is both well tilled and abundantly manured.

The following figures show the large quantity of phosphoric acid contained in the soil, and the small proportion of it which is annually removed by crops. The soil of a field weighs at least 100 tons per inch in depth. A good soil contains 0·25 per cent. of phosphoric acid, or 5 cwt. per inch in depth. A crop of wheat removes from 12 to 15 lb. of phosphoric acid from each acre. If we assume the latter quantity, then an inch of soil would furnish sufficient phosphoric acid for 37 crops of wheat, and ten inches of soil would supply this compound to 370 crops of wheat. Other crops, no doubt, take much more phosphoric acid from the land; but, on the other hand, the fertilising resources of the super-soil admit of being largely replenished from the stores of phosphoric acid and potash buried in the sub-soil.

The chief objects accomplished by the operations of ploughing, subsoiling, grubbing, harrowing, and digging, are the exposure of the inner portions of the soil to the agencies of light and air. Under these stimulants the inert organic matter is converted into soluble plant-food, and the potash, phosphoric acid, and other fertilisers are abstracted from their stony cases, and prepared for the use of the crop. This mechanical treatment is also most beneficial in deepening the soil, whereby the roots of the plants grown in it can penetrate to greater depths in search of their food. Good cultivation also gets the land into *fine tilth*—that is, it reduces its particles to a tolerably uniform condition—increases its porosity, which augments its capacity of absorbing ammonia and carbonic dioxide from the air—and actually reduces a small portion of the soil to the finely pulverulent condition in which it proves most useful to vegetation.

The sub-soil is poorer in organic matter than the super-soil, and it contains in general less *potential* or *active* phosphates, potash, and other mineral foods of plants. For these reasons it is not desirable to bring up to the surface too much of the sub-soil; but it is useful to commingle annually a small quantity of the sub-soil with the surface one, so as to compensate for the loss of the fertilising matters which are continuously removed from the latter. A winter's action upon the crude sub-soil brought close to the air will render some of its dormant fertilising constituents immediately available for the use of plants.

It is most desirable that the mechanical treatment of the soil should not be deferred until spring. Autumn cultivation is now becoming the rule, and not, as was the case formerly, the exception. Land intended for green fallow crops should be ploughed very early in the winter, so as to render it more accessible to atmospheric influences. In the spring, grubbing is preferable to cross-ploughing, as it more thoroughly pulverises the soil. It is surprising how greatly the yield of turnips and mangolds is affected by cultivation. If the land be not thoroughly prepared for these crops, no amount of manure ordinarily applied will produce a large crop. As for the cereals, we have already shown that good crops may be produced without any manure, providing the tillage of the soil is thoroughly performed. Indeed, the term *manure* is derived from the Latin words *manus*, the hand, and *opera*, work, or hand-labour; and therefore, even according to etymology, manure and cultivation are equivalents.

Thorough drainage is one of the most important means of increasing the productiveness of soils. Excessive moisture acts injuriously by keeping the land cold; the sun's heat, instead of being usefully expended in warming the soil, is wasted in evaporating the superfluous water contained in it. 3,700 tons of water often fall upon an acre. In order to convert this liquid into steam or vapour, the heat derived from the combustion of 550 tons would be required. In the case of stiff, undrained clays, the large quantity of superfluous water which annually descends upon them is chiefly got rid of by evaporation—a process effected by robbing the soil of the sun's heat, which is

so indispensably requisite for the maintenance of the vigour of the cultivated plants.

Heavy, tenacious loams and clays are rendered more porous and friable by drainage; and after that operation their tillage can be performed with less difficulty and expense. Undrained soils are converted by heavy rains either (in the case of clays) into adhesive pastes, or (in the case of light lands) into puddles. On the contrary, a well-drained field will act under such circumstances like a water-filter, through which the water readily passes without effecting any important alteration in the condition of the filtering materials. Undrained stiff soils, when subjected to heavy rain, and then to strong heat, acquire a crust so hard that it is difficult to penetrate it. We have often seen seeds and potato-cuttings so firmly baked up in an undrained tenacious clay, that their vital powers were quite destroyed.

Unwelcome semi-aquatic plants often spring up in land which is badly drained, and they frequently succeed in overcoming and displacing no inconsiderable proportion of the plants under cultivation. When a marshy field is drained, the useless semi-aquatic plants spontaneously disappear.

The organic matter in wet soils decomposes very slowly, because of the exclusion of air. When by drainage the soil is rendered porous, the atmospheric oxygen penetrates to the organic matter, and converts it more expeditiously into water, carbonic dioxide, and ammonia—the substances that furnish to the vegetable the greater portion of its food. Every farmer knows that a wet field requires more manure than a drained one; in the former the manure remains much longer in an inert condition.

The water drained off from soils contains fertilising matters, more particularly compounds of nitric acid and sodium salts. The important fertilising substances, ammonia, potash, and phosphoric acid, are retained by the soil with great tenacity; and, on the whole, the water which passes off from cultivated soils carries with it but very small quantities of the food of plants. On the other hand, the soil is continuously receiving ammonia and nitric acid from the atmosphere.

TECHNICAL EDUCATION ON THE CONTINENT.—VIII.

BY ELLIS A. DAVIDSON.

TECHNICAL EDUCATION APPLIED TO FEMALES.

WHATEVER has been said of the unpractical character of the education of our boys refers with equal force to our girls, whose instruction in this country has until recently been of the most flimsy character, whilst in Germany it has always been recognised as in every way of equal importance with that of males.

It has been shown that technical education is that kind of instruction which shall fit the student for the business of life; and this applies to girls as well as boys.

Is it not just as necessary that the one should be educated for her position as the other? Assuredly females of every grade have sooner or later to take their share in the work of life; and therefore, whilst we are educating our boys, who are to carry on the work of this great country in the coming period, it is our bounden duty to extend equal care to their sisters: otherwise, although we shall render our future men more intellectual, and thus qualify them to elevate their positions, we shall be laying up for them a store of unhappiness, for as they become more enlightened, they will all the more require that those whom they may select as companions in life should be able to appreciate their acquirements and to sympathise with their labours.

Technical education on the Continent, then, is brought to bear upon females as well as males. And here, no doubt, many in this country, where the neglect with which female education has been treated is a national disgrace, will ask, "What can females learn?" For be it understood that, in order to account for their own selfishness and ignorance, it has been a fashion amongst some to speak disparagingly of female intellect.

It is not within the scope of these papers to enter upon the discussion of this point, especially as most of our best teachers declare that their experience shows them that no difference in the capability of receiving instruction exists between pupils in schools of either sex; whilst the desire to learn evinced by girls has always equalled, and often surpassed, that of boys.

That the action of the female brain takes a different direction to that of the male there can be no doubt; and is not this a beneficent ordination of an Allwise power who has assigned special duties and spheres of action to each? and thus it becomes the province of practical education to qualify them (as far as instruction can qualify them) to fill ably (as religious education should fit them to fill worthily) the duties of their position, whether as wives, mistresses, mothers, teachers, nurses, servants, or workers in any branch of industry.

It has been wisely said, "Man's home is the world, woman's world is her home;" but we must add that proper—we may call it *technical*—education is required for the efficient discharge of the relative duties of each; and further, that as many females are compelled by circumstances to make the world their home before they have a home in which to establish their world, as many have to enter the field of industrial work, it is necessary to inquire how these may be best fitted for the sphere in which they are to be placed.

Nor are the mere subjects which are to be taught to girls the only matters which are to be considered. The reasoning and practical tone given to the mind, the general training, the regularity of habits, and the economy of daily life, are all most important in the education of those who are to be the wives of the present, and mothers of the future generation; and if we would have the influence they will assuredly exert productive of good, we must let their instruction be such as will fit them to fill the important positions they are destined to occupy.

It is on his mother's knee that the child—"eyes raised to heaven, and small hands folded fair"—is taught to raise his heart to "Him who all things sees;" it is whilst walking with her that he learns to turn aside, lest he should injure the worm so marvellously made, and to watch the opening of the budding leaf. It is of her he asks, "Mother, what is the sun?" and to her he says, "What is there beyond the skies?" And then she reads to him out of this fair book of Nature; and the instruction she gives to him is wrapped in veneration for that great power, whose law, which governs all around us, is *science;* and the boy starts as a student with the best of all incentives to the acquirement of knowledge—a love of inquiry.

Thus, then, does woman lay the foundation of all education, and is the pioneer for all future teachers; and, therefore, no system of primary or technical education can be complete unless it is extended to females as well as to males.

THE TRADE SCHOOLS AT STUTTGARD.

The name by which these schools are known in Wurtemburg, "Fortbildungschulen," really implies their purpose better than any single word in our language: they are really schools for *further education* of persons who wish to continue their studies after they have left school for business.

For the full development of the purpose the schools are divided into the following departments:—

1. Evening schools, for pupils engaged in business in the daytime. 2. Sunday classes, for youth of both sexes, and adults. 3. Day school, for girls and women. 4. Drawing and modelling school, open throughout the whole day during the week.

Pupils on entering have their choice of attending such classes as they may deem necessary for their occupation, provided their previous education has fitted them for taking only special subjects; but pupils under sixteen must submit to the guidance of the teachers as to the branches which may be deemed necessary for them.

Pupils attending school, whatever their age, must in every way conform to the regulations; it being considered that the object of education (so eloquently expressed by the German word *bildung*, which means to "shape," or "form") is not merely to give literary or scientific instruction, but to form the habits and discipline the mind; and thus these schools fit the pupil for the business of life in other ways than in intellectual improvement. Breaches of discipline are, after repeated warnings, punished by dismissal.

Pupils under sixteen years must present a written introduction from their parent, or other respectable person, who will be required to sign a document, undertaking to be responsible for the proper observance of the rules on the part of the pupil.

The course of instruction, on the evenings of the week, comprehends the following subjects, and is carried on during the winter months only, with the exception of the advanced drawing and modelling classes, which are continued throughout the year:—

	Hrs. p. wk.
Modelling in clay and wax	4
Free-hand, Figure (from copies and casts), Landscapes, etc.	6
Free-hand Drawing for Wood and Copper-plate Engravers	4
Ornamental Drawing	6
Geometrical Drawing	2
Trade Drawing (for example):	
Drawing for Carpenters, etc.	6
Drawing for Turners, Stonemasons, etc.	6
Drawing for Locksmiths, Braziers, etc.	6
Mechanical and Architectural Drawing	6
Solid Geometry & Projection	4
Writing	$1\frac{1}{2}$
Mercantile Correspondence	$1\frac{1}{2}$
Book-keeping	$1\frac{1}{2}$
Arithmetic	3
Geometry	3
Mechanics	3
Physics	3
Chemistry	3
French—	
Elementary	$4\frac{1}{2}$
Advanced	3

Before pupils are admitted to the modelling class, they must have acquired a certain standard of power in ornamental and figure drawing.

The pupils who practise wood and copper-plate engraving find their own materials and tools. The pupils in the geometrical drawing class are expected to have previously mastered the elements of practical geometry, the use of mathematical instruments, etc., and must either have attended, or must in the same term attend, the class for projection.

In the "trade drawing" department the pupils are taught designing, and working out of the special drawing used in their branch of trade, to make or work from drawings. In the projection class the instruction enables the pupils to project elevations from plans or given data, to make sections, developments, etc. This branch is, in fact, the basis of all mechanical, architectural, and engineering drawing. In the class for the study of mechanics, the entire theories upon which machines are constructed are studied; and in the mechanical drawing class the designs are drawn to a given scale, together with details and working drawings.

The instruction in arithmetic and geometry is adapted to practical purposes, and every opportunity is taken to show their application in the other studies. The lessons in physics and chemistry, too, are arranged with a view to their use in trade.

DAY SCHOOL FOR GIRLS AND WOMEN.

	Hrs. p. wk.
(*a.*) General Course—	
Arithmetic	2
Trade Rules and Correspondence	2
Book-keeping	2
Writing	1
(*b.*) Advanced Course—	
English Language	3
French Language	3
German Language, etc.	2
Geography and History	2
Natural History, including also the knowledge of the food products used in a household, and domestic economy	2
Physiology as applied to health and sanitary principles	$1\frac{1}{2}$
Drawing and Painting	3
Pattern Drawing and Designing	3

Besides the above-named, classes are formed for other subjects when a sufficient number of names are entered to guarantee the attendance.

The teaching staff in the Stuttgard Fortbildung Schools is composed of professors of the highest standing, amongst them being three ladies.

The following statistics will give some idea of the extent of the operations of this school:—

Number of pupils:—

	Pupils		Teachers
In the Evening School	328	with	20 teachers.
„ Sunday Evening School	481	„	23 „
„ Commercial Evening School	178	„	16 „
„ Female Evening School	130	„	10 „
	1117		69 „

TRADE SCHOOL AT ULM.

The Trade School at Ulm, though based on the same scheme as that of Stuttgard, has, like all the other schools, its individual peculiarities; and, therefore, in pursuance of the object in view—viz., to show the systems of various technical schools—a brief notice of it is here given. The classes begin in October, and close at the end of April; but those for the study of the French and English languages are continued throughout the year.

The hours of attendance are, for the general studies, from 8 to 9.30 in the evening; and for languages, from 7 to 8 o'clock in the morning during the winter months, and from 6 to 7 in the summer. Besides this, there are art-classes open all day in the winter, to enable working men who may not be fully employed at that season—such as carpenters, masons, slaters, etc.—to improve themselves in the studies connected with their respective occupations.

The school consists of two departments—viz., the Commercial and the Trade Schools. Pupils having paid the fees for the commercial school are free to attend the trade school, should the arrangements of the lessons permit, without further payment; students in the trade school are admitted free to the German classes in the commercial school, and, on the payment of a very small extra fee, to the English and French classes. Below is given the time table in the Trade School at Ulm.

The number of students attending the school at Ulm averages 739, under the care of 22 teachers. This teaching staff is perhaps the smallest of any in the great group of schools—giving an average of rather more than 33 pupils to each teacher; whilst it will be seen that, in the Stuttgard school, 1,117 pupils are taught by 69 teachers, or rather less than 17 to each. Seventeen pupils to each teacher seems to be about the average throughout this class of schools in Wurtemburg.

TIME-TABLE IN THE TRADE SCHOOL AT ULM.

		MONDAY.	TUESDAY.	WEDNESDAY.	THURSDAY.	FRIDAY.	SATURDAY.
	Drawing. Every Evening from 8 to 10.	Free-hand Drawing and Modelling.	Linear Drawing. Free-hand Drawing and Modelling.	Free-hand Drawing and Modelling.	Linear Drawing. Free-hand Drawing and Modelling.	Free-hand Drawing and Modelling.	Linear Drawing. Free-hand Drawing and Modelling.
Trade Department.	Elementary Course, 8 to 9.30 Evening.	Trade Arithmetic. (Course A.)	Trade Arithmetic. (Course A.)	Business Composition and Correspondence. Geometrical Drawing.	Trade Arithmetic. (Course B.) Geometry.	Trade Arithmetic.	Business Composition & Correspondence. Geometry.
Trade Department.	Advanced Course, 8 to 9.30 Evening.	Chemistry. Descriptive Geometry.	Business Correspondence.	Physics. Trade Book-keeping.	Chemistry.	Descriptive Geometry.	Physics.
Commercial Department.	7 to 8 Morning.	English (A). French (B).	English (B). French (A).	English (A). French (B).	English (B). French (A).	English (A). French (B).	English (B). French (A).
Commercial Department.	8 to 9.30 Evening.	English and French Correspondence. Commercial Arithmetic.	General Office Instruction.	Commercial Arithmetic.	Exchanges. Commercial Arithmetic.	Office Instruction. German Literature.	Commercial Arithmetic.

APPLIED MECHANICS.—V.

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HYDRAULIC MACHINERY.

THE machines which may be classed under this heading contain some of the most beautiful examples of modern engineering skill. Water has been applied with the greatest success as a means of transmitting power for a great variety of objects. For this purpose its remarkable property of incompressibility is peculiarly adapted. We do not mean to say that water is absolutely incompressible; but it may practically be so considered, for the amount of compression it undergoes is exceedingly small.

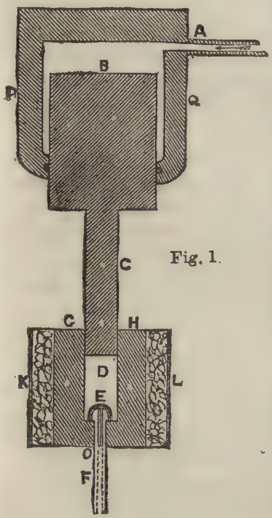


Fig. 1.

The principle and construction of the hydraulic press has been already fully explained in the pages of the POPULAR EDUCATOR (see "Hydrostatics"—I., Vol. II., page 366). To this account we therefore refer the reader for a full description of this powerful machine. We shall mention one or two important applications of the hydraulic press, and we shall then consider some other machines which are worked by water at high pressure.

The first example we shall take is the application of the hydraulic press to the manufacture of leaden tubing. The quantity of lead annually consumed in making gas-pipes and water-pipes is enormous, so the aid of machinery has been called in whenever possible. The process is one of great interest. The tubes are forced by pressure out of solid lead, which is warmed up to a certain temperature, though still far from being melted.

The apparatus by which this is done is shown in Fig. 1. P Q is the hydraulic press. This consists of a very massive iron cylinder, into which the piston, B C, fits. A is the pipe by which the water is forced into the space above the piston. The pumps which inject the water are not shown in the figure; they are worked by a steam-engine. The piston is thus pushed downwards with enormous force. The plunger is narrowed at the end, and turned so as to fit tightly into a very powerful iron cylinder, G H. It is in the space D, in the hollow of this cylinder, that the lead is placed from which the pipes are to be made. This cylinder is filled by pouring in molten lead, which is then allowed to solidify. Round this cylinder is a second cylinder, K L, containing a fire for the purpose of keeping the lead at the temperature required. This lower cylinder, containing the lead, is connected with the upper cylinder, P Q, by means of very powerful framework, so that when the pressure is exerted the piston must be forced down into D.

The most essential feature of the apparatus is shown at E. At O is a hole in the bottom of the cylinder, which is carefully turned, and is exactly the external size of the pipe required. A small arch is shown at E; from the top of this a mandril descends down through the hole. This mandril is exactly the internal diameter of the pipe, so that when the lead is forced between the mandril and the cylindrical hole, it is formed into the required dimensions. Under the enormous force with which the lead is compressed it becomes as yielding as putty is to an ordinary pressure. It appears very surprising at first to find that the lead is forced around the sides of the arch at E, and yet that the pipe is perfect and bears no traces whatever of the division which it must have undergone. In the earlier stages of the manufacture it was not believed that the lead would be sufficiently plastic, and consequently the mandril was fixed directly into the plunger, C, so as to avoid the difficulty of the arch. It is, however, found that equally good tubes can be made when the mandril is supported by the arch, and so this more convenient arrangement is adopted. It is very remarkable to see the lead pipe rapidly flowing from the bottom of the cylinder. It is thus made in lengths, each of which contains one charge of the vessel, G H, called the *container*. By altering the size of the hole and of the mandril different sizes of pipes can be produced.

Hydraulic pressure is especially convenient for the purpose of transmitting power. Water can be conveyed through pipes to any distance, and if force be employed in compressing the water into a pipe at one end, the water will exert force to get out at the other end. Hence we may consider that the water is just the means of transmitting the power from one end of the pipe to the other. For this purpose water is more convenient than steam, for though the steam could be conveyed through pipes, yet special means must be employed to keep the steam hot enough to prevent its condensation. Air is sometimes used for the purpose of transmitting power when from any cause the use of water is inconvenient.

As an example of this application of hydraulic power, we shall describe the machinery which is erected at Waterloo Dock, Liverpool, and at various other places throughout the country. The machinery at the place mentioned is on a very large scale, and has a great number of functions to fulfil: the dock-gates have to be closed and opened, the vessels have to be unloaded, the corn has to be raised and carried about to different parts of the immense granaries, which are capable of containing many thousands of tons. These different duties demand special machines in different parts where the work is required to be done. To accomplish this it would be very uneconomical of power, and otherwise inconvenient, to have a special engine for each machine. Most of these machines are only worked occasionally: for example, to open the dock-gates an engine of very considerable power would be required, but the gates only require to be opened now and then, and it would be very undesirable to have to maintain a fire all day for the purpose of opening the gates a few times during the twenty-four hours.

Similarly, the other machines are only worked intermittently, and out of all the machines that are employed, perhaps more than a quarter are never simultaneously in action. The case, therefore, is this: an engine, one-fourth of the power which would be necessary to turn all the machines together, will yet be sufficient for ordinary purposes, provided we have convenient means of applying its power wherever it may be wanted. Some of the machines require a great deal of power, others not so much, and therefore we also require to save up the power of the engine when working the small machines in order to have enough when a greater exertion is demanded. Water affords a most convenient means of obtaining these objects. An engine of sufficient power supplies the energy; this energy is stored up by the engine in what is called an *accumulator*, and from the accumulator it is distributed by means of water-pressure to the different machines that require it.

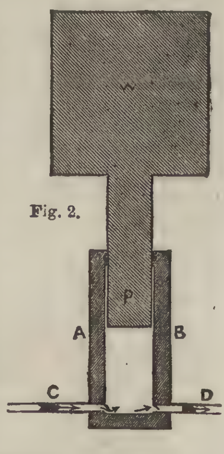


Fig. 2.

The accumulator is shown in Fig. 2. W is an immense weight of about ninety tons. There are guides introduced in order to restrain its motion to sliding up and down vertically, and prevent it from falling to one side. These guides are not shown in the figure. At the bottom of this weight is a plunger, P, which works tightly into a cylinder, A B. This cylinder is kept filled with water by the pipe C; the water is pumped into it by very powerful force-pumps, to work which the whole power of the engine is employed; forcing water through the pipe C into the cylinder is, in fact, the duty of the engine. Let us suppose a cock on the pipe D is turned off, then the water, when forced into the cylinder, must raise W. It is prevented from pushing P entirely out of the cylinder by a self-acting contrivance. When the weight W ascends to a certain point it acts on a lever which closes the valve supplying steam to the engine, and therefore stops the entry of water at C. Hence the engine will be constantly striving to keep the cylinder full.

The pipe D communicates with all the machines throughout

the docks which are to be worked by the pressure of the water. The water is at an enormous pressure in the cylinder. We can easily calculate its amount when we know the diameter of the cylinder and the weight of W.

Let us suppose that the diameter of the cylinder is 10″, and that the load W is 90 tons. The area of a circle is

$$\frac{22}{7} \times (\text{radius})^2.$$

From this it will be seen at once that the area of the end of the plunger is

$$22 \div 7 \times 25 = 78{\cdot}5.$$

Hence we have a pressure of 90 tons upon a surface of 78·5 square inches, and therefore the pressure on each square inch is

$$90 \div 78{\cdot}5 = 1{\cdot}15 \text{ tons.}$$

This enormous pressure is doubtless to some extent lost by friction through the ramifications of pipes by which the water is distributed; but we may probably assume that in general the pressure must be nearly a ton on the square inch. At this enormous pressure a very little water does a very great quantity of work. Let us calculate how much work is done for every pint of water that leaves the cylinder. A pint of water contains 35 cubic inches; hence, since the area of the plunger is 78·5 inches, the weight must descend

$$35 \div 78{\cdot}5 = 0{\cdot}45 \text{ inches,}$$

in order to expel a pint of water along the tube D. Now, how many units of work has the cylinder exerted? This is to be found by multiplying its weight in pounds by the distance through which it descends in feet.

$$0{\cdot}45 \div 12 = 0{\cdot}0375$$

is the distance in feet, and

$$2240 \times 90 = 201600$$

is the weight in pounds, hence the number of units of work is

$$201600 \times 0{\cdot}0375 = 7560;$$

that is, it would raise 7,560 pounds through one foot, or one ton through

$$7560 \div 2240 = 3{\cdot}4 \text{ nearly.}$$

Hence, by the consumption of one pint of water a ton weight can be raised in any part of the building through a distance of more than a yard.

The mode of working the machine will be easily understood. The weight is constantly rising or falling, rising when no large machines are drawing off the water through D, and falling when the machines are using the water faster than the engine is sending it in. Thus, when little water is used it is stored up until there is a greater demand for it.

The machines which are worked by the power of the water are of different kinds. We shall say a few words about the construction of the most important of them. The corn is taken out of the vessels by the use of machinery. An arm projects from the warehouse, which supports an apparatus by means of which little buckets upon a band descend into the hold and return filled with corn. This corn, when the buckets reach the top of the arm, is discharged into a shoot that carries it into the store, and the empty buckets descend for another load. By this contrivance a vessel is unloaded with great expedition. This machine is worked by the pressure of the water.

The corn is also hoisted from the bottom of the warehouse to the top by means of an hydraulic hoist. This is a very remarkable machine, and a description of it is the more necessary, as it has come into very extensive use.

The principle of the hydraulic hoist may be understood by Fig. 3. This diagram shows the essential principle of the machine, reduced to as simple a form as possible for the purpose of explanation. In consists essentially of an hydraulic press, and two pulley-blocks, one of which is attached to the cylinder, and the other to the plunger. The corn is raised in loads of about a ton, from the bottom of the store up to the top, through, perhaps, a height of 60 feet or more. It is, therefore, necessary to pull in the chain which is attached to the lift through a length of 60 feet.

If we have a pair of four-sheave pulley blocks, and are raising weights in the ordinary way, it is evident from the account we have already given in Lesson II., that 8 feet of chain must be pulled out for every 1 foot that the load is raised. Now, if the pulley-block be so well constructed at the axles of the sheaves that there is as little friction as possible, the weight will overhaul; that is, when lifting a weight, if we release the lifting chain the weight will descend. It follows, then, that for every foot the weight descends 8 feet of chain will be pulled in between the blocks. For this to occur we must have, as already explained, less than half the total force lost by friction. Supposing, now, there were a weight of 8 cwt. being raised, a force of 1 cwt. would be necessary to lift it without friction, and about 2, or a little less, with friction; but suppose the weight to descend, what strain can it produce on the lifting chain? It would produce a strain of 1 cwt. in a frictionless block, but owing to friction the actual strain is less than this. Let us suppose it to be $\frac{1}{2}$ cwt., then the weight of 8 cwt. descending will raise $\frac{1}{2}$ cwt. 8 feet for every foot it descends. Hence we learn that, if the blocks of a pair are forced asunder by a great pressure, the chain will be drawn in through a distance 8 times as great as the distance through which the blocks are forced apart, and a strain will be exerted upon the chain thus drawn in, which we may take as about one-sixteenth of the force pushing the blocks asunder.

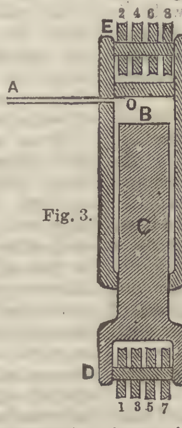


Fig. 3.

Let us now apply these considerations to Fig. 3. The two blocks are shown at D and E; but the chain is not introduced, for the purpose of keeping the figure clear. The block E is firmly attached to the cylinder, and the lower block is forced away from it by admitting water at high pressure through the pipe A. The chain is attached to the upper block at O, it then passes down under the pulley 1, over 2, under 3, over 4, under 5, over 6, under 7, and over 8; to the free end hanging over 8 the lift is attached. Now, supposing the blocks be forced asunder with a pressure of about 16 tons, it is evident that the free end of the chain will be drawn in with a force of one ton, and will, therefore, be able to raise a load of 1 ton. If the stroke of the plunger be 8 feet, the lift will be raised 8 × 8 = 64 feet. As the pressure on the water is very great, the cylinder need not be very large in order to produce sufficient pressure.

There is considerable loss of power by friction in this arrangement; but its compactness and convenience quite outbalance this slight disadvantage. The hydraulic hoist has but few parts, it cannot easily go out of repair, and it can be applied wherever a pipe can be laid to carry the water to it.

After the load has been raised the water has done its work, and a valve is opened to permit its escape. The weight of the lift then pulls the chain, this raises the plunger and expels the water, and the apparatus is ready for another load.

The corn, when raised by the lift, is poured into a hopper, from which it descends to a weighing machine, which weighs it in loads of nearly a ton at a time. It is then carried by machinery to that part of the store in which it is to remain. The machinery by which this distribution is effected is very interesting.

A large band, about 18″ wide, runs along the top floor of the building. This band is supported by rollers, and is worked by a small water-pressure engine.

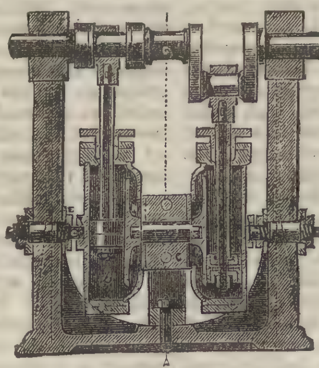


Fig. 4.

A view of a water-pressure engine, suitable for such a purpose, is shown in Fig. 4. There are two small cylinders resembling steam cylinders, and the water is admitted to the sides of the piston alternately, just as the steam works the piston in the steam cylinder. These cylinders oscillate, and the rod of each is connected with a crank on the horizontal shaft. The cylinders need only be of small dimensions, for the

pressure of the water vastly exceeds any steam-pressure which could be used.

The machine shown in Fig. 4 has been constructed by Messrs. Ramsbottom, of Leeds. We cannot do better than give the account of its use in the makers' own words :—

"The great requisite in water machinery is to maintain a constant and equal outflow to avoid concussion, for when the momentum of water has been generated in a given direction, and its motion is suddenly intercepted by a barrier in the form of a stop-tap, or imperfect valvular action, the result is not only destructive to the machine, but represents a considerable expenditure of mechanical effect. For water-engines are nearly always double acting, and in such cases the *valvular* action is duplicate, and we have made it a matter of the greatest importance in valvular construction to open and close the supply and exit ports slowly, and in such manner that the feed-way leading to one piston shall be in full effect when the other is absolutely closed at the termination of its stroke, and thus one set of feed and exit ways are dying gradually away to termination of stroke as the other set are opening towards full effect on return-stroke of its piston; and thus a valvular action is obtained, which not only avoids concussion but the loss of effect by avoiding the counteraction of pressure and untimely supply. We have several hundreds of water-engines employed for various kinds of work, with valvular action, as above described, and their efficiency, compactness, and convenience clearly show how much the advantages of hydraulic power are under-estimated in many of our largest towns and cities, where numerous mechanical operations might be better performed by this than any other kind of power whatever. A constant supply and adequate pressure in London would be of immense value, for unlike steam this power is neither dangerous nor offensive, but is contributive to health and cleanliness; and as in many cases the water passes directly in a pure state from the engines to the sewers, it forms a valuable flushing agent after use. Most machinery of a domestic character could be driven by water power, thus avoiding much personal attention; and the folding, pressing, and raising of goods of various kinds, as well as the working of hoists, the grinding of coffee or drugs, the driving of book-printing machines, and other uses too numerous to mention, attest the importance of soliciting increased public attention to this most natural of all the sources of motive power."

On the shaft, which is turned round by a water-power engine, a large pulley is fastened. This pulley is enveloped by the band which runs on the rollers, and when it revolves it gives the band motion.

After leaving the weighing machine the corn passes into a second hopper, from an opening in which it is poured out upon the rapidly-moving band, and is carried along by the band at a prodigious rate. About 50 tons of corn can be carried on one of these bands in an hour. By an ingenious arrangement the corn can be thrown from one band upon another at right angles, and can thus be made to turn round a corner. By means of shoots it can be delivered into any corner of the building.

There are many other applications of water-pressure hardly less interesting than those we have been considering; but our space will not admit any further discussion of them.

VEGETABLE COMMERCIAL PRODUCTS.

VIII.

FLESHY FRUITS (*continued*).

THE LEMON (*Citrus limonum*, L.).—This plant is a native of the Himalaya mountains. It appears to have been brought to Europe about the time of the Crusades. The lemon is now cultivated in all warm climates. The principal supplies to our markets are received from Italy, Spain, Portugal, Trieste, and South Tyrol. The juice and rind are both officinal. Lemon-juice is peculiarly grateful and cooling, and is much used in the preparation of effervescing draughts, and as a beverage in febrile complaints. The juice owes its sourness to the presence of a peculiar acid, called *citric*, which is easily separated by chemical means. It is one of the most powerful anti-scorbutic medicines known. That dreadful disease, the scurvy, has hardly been known in our navy since limes and lemons were ordered by law to be carried by all vessels sailing to foreign parts.

There are several other species of *Citrus* which are largely imported; as, for instance, the *Citrus limetta*, or lime, which is about one-third the size of a common lemon, and which is exported in the green state, in order to preserve the delightful aroma of its rind. The preserved lime comes to us in small kegs of about 7 lb. weight. The *Citrus Bergamiæ*, or bergamot, bears a fruit closely resembling the lemon. As a preserve it is used as a substitute for citron, but its chief value lies in the oil obtained from it—the well-known bergamot so much used in perfumery.

GRAPES (*Vitis vinifera*, L.).—The fruit of this vine not only furnishes us with a variety of wines, but is itself imported into this country both in the fresh and the dried state. We receive comparatively few grapes in a fresh state; about 300 tons arrive every autumn from Sicily, Lisbon, and Hamburg. They suffer in their flavour from being closely packed, and still more from the use of sawdust as a packing material. Raisins, or dried grapes, are far more abundantly imported. These are prepared sometimes by cutting the stalks of the bunches half through, and leaving them suspended to the vine until sufficiently dry, which in this state they rapidly become, without losing any of their fine flavour or bloom; the usual mode is to expose the grapes to the sun and air for a while, then lay them out in rooms, and sprinkle them with water in which soda or potash has been dissolved. This causes the sugar of the grape to candy, forming those little sweet lumps so well known in the common raisin. The differences amongst the raisins are caused entirely by difference in their mode of culture or curing. Thus we receive stoneless sultana raisins from Smyrna, in Turkey; fine muscatels, or sun-dried raisins, in bunches with the stalks still attached, from Malaga; Damascus raisins, much larger than the sultanas, stoneless also, and preferred to the Smyrna raisins, from Damascus; and lastly, the ordinary raisins from Valencia, and from the same countries and ports where the grape is cultivated.

Currants are only the raisins of a small grape, also deficient in seeds or stones, growing in huge bunches, often as much as eighteen inches long, and of proportionate breadth. They are trod into large casks, and exported. Enormous quantities are cultivated in the Grecian islands, principally in Corfu, Zante, and Ithaca. Originally, Corinth was the principal place where they were raised, whence the name "Corinths," from which the word "currants" has been derived. In 1867, 1,002,366 cwt. of this much-esteemed fruit were imported into the United Kingdom, and about 392,322 cwt. of the other and larger varieties of raisins.

FIG (*Ficus carica*, L.; natural order, *Urticaceæ*).—This is a very valuable and extensive genus of tropical and sub-tropical plants, some of the species attaining an enormous size, as the *Ficus Indica*, or celebrated banyan tree. The fig tree, originally a native of Asia, now flourishes in Southern Europe, on all the islands in the Mediterranean, and especially in Asia Minor, Northern Africa, and the Canary Islands.

The fig, considered botanically, is a very remarkable form of fruit, being just the reverse of that of the strawberry, in which the minute pistils are scattered over the exterior of the enlarged succulent receptacle; whereas in the fig the inflorescence or position of the flowers is concealed within the body of the fruit. There is sometimes a failure in the fig crop, when it is not properly attended to, in consequence of the pistils of the florets not becoming duly fertilised by the pollen of the stamens. It is supposed that this operation is caused naturally by the entry of insects through the very small orifice which remains open in the flowering fig; the fig-growers therefore adopt an artificial means of ensuring fertilisation—a small feather is inserted and turned round in the internal cavity. This operation is called "caprification."

Figs are sent to us in large quantities from Turkey and Greece—those from Turkey being the best. The fig, after having been gathered from the trees and dried in the sun, is usually packed in square or circular boxes, the latter being called "drums." A few bay leaves are put upon the top of each box, to keep the fruit from being injured by a grub, which feeds on it and is very destructive. The Maltese figs are very good, but those which come from Smyrna, called "Eleme," or "Elemi," are the best.

The fig is nutritious, laxative, and demulcent, acting gently in cases of habitual constipation. Roasted and split it is some-

times applied to gum-boils and other circumscribed maturating tumours. It was used by Hezekiah as a remedy for boils 2,400 years ago. (See Isaiah xxxviii. 21.)

The annual import of figs into the United Kingdom is upwards of 700 tons.

PRUNE (*Prunus domestica*, variety, *Juliana*; natural order, *Rosaceæ*).—Dried plums, under the names of prunes and French plums, form an important article of commerce. The prune is the Julian variety of the common plum dried in the sun; the prunes are then thrown together and pressed into barrels. We receive them in large quantities from France. The imports in 1860 amounted to nearly 300 tons.

Prunus domestica, variety *Catherinea*, is the French plum or table prune. These are more carefully prepared for market. They generally come over in very elegant boxes called cartons, into which they are neatly packed one by one. In 1851 about 90 tons were imported.

THE DATE PALM (*Phœnix dactylifera*, L.).—This palm has been known and prized from the earliest antiquity; it is frequently referred to in the Bible. The fruit is very nourishing and wholesome, and grows in bunches weighing from twenty to twenty-five pounds. Every part of this tree is useful. Its hard wood is employed for building; its leaves are made by the natives into mats, baskets, and drinking bowls of great neatness; its seeds are ground to make oil; and its fermented sap forms an excellent wine.

THE DATE PALM.

In Corsica, Sardinia, and in Southern Greece the date palm is planted only as an ornamental tree, as its fruit does not mature in these parts, or ripens only imperfectly. In the very warmest districts of Spain, around Valencia, the fruit comes to perfection, and is exported. The date palm is indigenous to Arabia and Northern Africa, where it is very abundant. In those countries plantations of these trees are sold as estates, and are often the wedding portion of the bride. In some parts of Arabia this palm sometimes forms almost impenetrable forests when neglected by the Arab of the desert, who usually considers every kind of cultivation beneath his dignity. More frequently, however, it is found in a solitary state near a spring, thus presenting to the thirsty traveller a welcome signal, which assures him of water for refreshment, and of a friendly shade for repose.

The best dates come to us from Tunis *viâ* Marseilles. The quantity annually imported into England is from ten to twelve tons.

POMEGRANATE (*Punica granatum*, L.; natural order, *Myrtaceæ*).—A small evergreen shrub, resembling a myrtle, with numerous slender spinose branches; leaves opposite, entire, lanceolate, bright green, and sessile; flowers large, terminal, and rich crimson in colour. The fruit is about the size of a large poppy head, and similarly shaped; its rind hard, leathery, and beautifully coloured; when ripe, golden-yellow, with a rosy tinge. When the rind is broken, the interior of the fruit is found to be filled with numerous seeds, each enveloped in a rose-coloured pulp, packed together in two rows, with partitions of pith between them, and closely resembling red currants.

There is scarcely a part of the pomegranate that is not either useful or agreeable. The pulp of the fruit is refreshing to persons suffering from fever. The seeds and flowers dried form a valuable medicine, and are used in dyeing, and the rind is employed in tanning and preparing the finer kinds of leather, as the morocco, so much used for bookbinding.

The pomegranate is a native of Northern Africa, Syria, and Persia, but it is now naturalised in the warmer parts of Europe, the West Indies, and the Southern States of the American Union. It was known to the ancients, is mentioned by Homer, and also frequently referred to in the Bible. We receive annually a considerable number of chests of pomegranates from Portugal, and sometimes from Barbary. This tree is frequently cultivated as much for the beauty of its flowers and foliage as for its fruit.

TAMARIND (*Tamarindus Indica*, L.; natural order, *Leguminosæ*).—This is a large tree, with spreading branches, and abruptly pinnate leaves, the leaflets closing in the evening or in cold, moist weather, like those of the sensitive plant. The flowers are in simple racemes, the petals yellowish, variegated with red veins; these are succeeded by an oblong, compressed, one-celled, brittle, brown pod, from three to four inches in length, which encloses from six to twelve brown, flattened, hard, polished seeds, enveloped in a soft pulp, the whole being held together by a number of thick root-like fibres which penetrate it in all directions.

The tamarind is common in the East Indies, where it is indigenous, and grows in great perfection. It is now introduced

and extensively cultivated in the West Indies and in South America; but the fruit there is not equal to the East Indian, having much less saccharine matter in the pulp. The tamarinds from the East Indies are darker, have a larger and sweeter pulp, and can be preserved without sugar; those from the West Indies require sugar, and are sent over preserved in a thick saccharine syrup.

The tamarind pods are gathered when ripe, a fact known by their brittleness; the fruit is removed from the pod, placed in layers in a cask; boiling syrup is poured in; and when the cask is filled, and its contents have cooled, it is headed down for exportation.

In tropical countries the tamarind is much esteemed for its cooling qualities; its taste is acid and agreeable, and it assuages thirst. Tamarinds are principally employed in this country to form cooling medicinal drinks. Large quantities arrive annually from the East and West Indies.

BANANA (*Musa sapientum*, Tournef.; natural order, *Musaceæ*).—This may be called a stemless plant, for its gigantic leaves, with their long petioles, are sheathing and imbricated at their base, and form, by their union, a spurious trunk, often many feet in height. The leaves are from four to six feet in length, rounded at each end, and about eighteen inches in breadth throughout their whole extent; they have a strong mid-rib, parallel, lateral veins, and are of a beautiful emerald-green colour. The flowers are spathaceous, and produce large clusters of succulent indehiscent fruits, each fruit being an inch in diameter and about six inches in length. When ripe, the banana acquires a rich golden-yellow colour; the outer envelope or exterior of the fruit is easily removed; the inner portion consisting of a rich cream-coloured pulp, containing a considerable quantity of sugar and starch.

The banana forms an important article of food in the tropics. Some idea of its fruitfulness may be gathered from the statement of Humboldt, that the same space of ground which will grow thirty pounds of wheat, or ninety-nine pounds of potatoes, will afford 4,000 pounds of bananas. Those intended for exportation are generally gathered green and unripe, but soon acquire, on being kept, that golden tint which marks maturity. Several other species of *Musa* produce similar fruits. *Musa paradisiaca* yields the plantain, a fruit bearing a close resemblance to the banana, and equally nutritious.

PINE-APPLE (*Ananassa sativa*, Lindl.; natural order, *Bromeliaceæ*).—This is a stemless plant with rigid, re-curved, channelled, and spinose leaves. The fruit is called in botany a *sorosis*, and consists of a union of the ovaries, floral envelopes, and the succulent axis of the inflorescence, which become pulpy and confluent with each other. The fruit is so acid in the wild state, that when eaten it removes the skin from the lips and gums; cultivated, it becomes sweet and agreeable to the palate, and richly aromatic.

Originally indigenous to the Bahama and Bermuda Islands, the pine-apple, owing to its value as a fruit, and its capability of becoming naturalised, is now cultivated, not only in the East Indies and Africa, but in all parts of the world where it can be grown either by natural or artificial means. Owing to the introduction of steam navigation, vessels can now bring ripe pine-apples from the West Indies to England in pretty good condition; and their importation has become an extensive trade, more than 200,000 having been brought from the Bahamas in 1851. Consequently, this fine fruit is often sold in London and other large towns at a cheap rate compared with the price asked for those grown in English hot-houses. English-grown pine-apples are worth from ten to twelve shillings per pound, whilst those imported rarely exceed half-a-crown for the entire fruit. Inferior pine-apples are frequently sold in the streets in slices at a penny per slice.

(*b.*) NUTS.

HAZEL NUT (*Corylus Avellana*, L.; natural order, *Cupuliferæ*).—This familiar edible nut is found growing wild in the United Kingdom, in the forests of all parts of temperate Europe, and in many places in Asia. The consumption is immense, especially amongst children; and many thousand bushels are annually brought to this country from Spain, Sicily, Smyrna, and other places. The filbert is only an improved variety of the common hazel nut, and although occasionally imported, is usually cultivated in sufficient quantities in England to supply the demand.

COLOUR.—V.

By Professor CHURCH, Royal Agricultural College, Cirencester.

THE SECONDARY AND TERTIARY COLOURS—CONTRASTS OF TONE AND OF COLOUR.

Secondary colours may now engage our attention. On referring to the central figure in our coloured diagram, it will be seen that the three primaries occupy the angles of the first triangle, and the three secondaries the angles of the second. If we represent the same arrangement without colour (Fig. 13), we shall be able to point out very clearly the constituents of each compound colour. The three small triangles marked I. contain the three primary colours, while those marked II. contain the three secondary colours. When equivalent quantities of yellow and red are mixed, orange is the result—a secondary colour equally distant from yellow on the one side and red on the other. It is commonly held that, with material pigments, three parts (by surface measurement) of a good yellow require five parts of a good red to form the normal orange. The eight parts of the normal orange formed in this way will serve as a complementary equivalent to eight parts of the normal blue. But, after all,

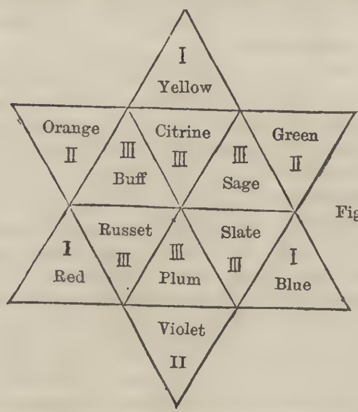


Fig. 13.

these and similar numbers are merely approximate, serving just to indicate the direction in which one coloured constituent must preponderate over another in such mixtures as the secondary colours. When yellow and red are mixed in proportions differing from those necessary to constitute the normal orange, the resulting colour becomes a yellowish-orange or a reddish-orange, according to the predominance of either of the constituent primaries: countless variations of a secondary colour in this direction are possible. Indeed, as we have already shown, most of our coloured materials, usually regarded as exhibiting primary colours, in reality furnish us with secondary hues of this kind, though their mixed character is not perceived by the unassisted vision.

The following list shows the imaginary or theoretical composition of the three secondary colours, and their six chief modifications or hues. The letters Y, R, and B represent the equivalent proportions of the three primaries—yellow, red, and blue; the equivalent of yellow being assumed to be 3, of red 5, and of blue 8:—

SECONDARY COLOURS.

Y + R = Orange.
R + B = Violet.
B + Y = Green.

SECONDARY HUES.

2Y + R = Yellowish-orange.
Y + 2R = Reddish-orange.
2R + B = Reddish-violet.
R + 2B = Bluish-violet.
2B + Y = Bluish-green.
B + 2Y = Yellowish-green.

Orange.—This colour is the most powerful and brilliant of the three normal secondaries. It is seen in the pigment known as cadmium yellow (the cadmium sulphide), and in the skin of a rich-coloured ripe orange. To make a pure and bright orange by mixture, it is essential that the yellow pigment should incline to red rather than to green, and the red pigment to orange rather than to blue. If the contrary be the case, and a greenish-

yellow pigment be mixed with a red, or a yellow with a violet-red, a certain amount of grey is produced by the combination of the three primaries present, and a dulled tone of orange is the result. The worst effect of this kind is produced when a greenish-yellow is mixed with a violet-red. Gamboge and carmine form an orange far inferior in purity to that produced by the admixture of chrome yellow and vermilion.

Violet is the least powerful of the secondary colours. The aniline dye known as mauve may be taken as somewhat near the normal violet. Many other artificial colouring matters made from the products of coal-distillation also approach this beautiful colour. Violet usually appears much redder and duller by candle or gas-light than by daylight. The yellow and orange rays which are present in peculiar abundance in most artificial lights, neutralise some of the blue in the violet, forming therewith grey, and at the same time setting free, as it were, the red element of this secondary combination. To make a pure and bright violet by mixture, it is essential that the red pigment should incline to blue rather than to orange, and that the blue pigment should incline to red rather than to green. Vermilion and cobalt produce a very dull and earthy-looking combination, owing to the presence of orange in the former colour and green in the latter. Carmine and ultramarine afford a more satisfactory mixture.

Green is more vivid than violet, but less so than orange. It occupies a considerable space in the solar spectrum, where, however, much of the green light has a yellowish hue, and some of it inclines towards blue. Emerald green is in reality far from reflecting pure green light only to the eye. Its spectrum is simply deficient in red and orange rays, yet even these are by no means absent. The new "aniline green," which retains its characteristic and brilliant colour by artificial light, absorbs, when of sufficient purity and in sufficient amount, nearly all rays except the green. When a piece of cotton dyed with this green is interposed between a light and the spectroscope, it will be found that about six thicknesses of the fabric are requisite to strain off all the red rays. But this result may be accomplished more easily by a solution of the colouring matter; for in this case there are no interstices through which light can pass, and thus escape the selective absorption of the pigment. Viridian, the beautiful and permanent chrome green introduced very recently, transmits the green rays or green portion of the spectrum unchanged, but along with them a small portion of the red and of the blue rays. In producing a green by admixture of yellow and blue, it is important to take a yellow and a blue both free from red. A greenish-yellow and a greenish-blue, or else a pure yellow and a pure blue, may be successfully used. Notwithstanding its brilliancy, cadmium yellow, which is really an orange, cannot be made to yield a satisfactory green by the addition of any kind of blue pigment.

Tertiary Colours have now to be considered. Referring back to our diagram (Fig. 13), we find six spaces marked III. Each of these spaces is immediately contiguous with a space (marked I.) assigned to a primary, or to a space (marked II.) assigned to a secondary colour. We have already alluded to the fact that the so-called tertiary colours ought, strictly speaking, to be regarded as nothing more than dulled tones of the primary and secondary colours. Indeed, it is impossible, on the theory of the three primaries together forming grey, to have any colour which shall exhibit the colour-effect of more than two of them together. An examination of the composition of the tertiary colours will explain this point. Using again our former symbols for the primaries, and letting Gy stand for grey, we may express the constituents of the six normal tertiaries thus:—

$2Y + R + B = Y + Gy$ = Yellow-grey, or *citrine.*
$2Y + 2R + B = Y + R + Gy$ = Orange-grey, or *buff.*
$Y + 2R + B = R + Gy$ = Reddish-grey, or *russet.*
$Y + 2R + 2B = R + B + Gy$ = Violet-grey, or *plum.*
$Y + R + 2B = B + Gy$ = Bluish-grey, or *slate.*
$2Y + R + 2B = Y + B + Gy$ = Greenish-grey, or *sage.*

It is commonly stated that the tertiary colours are compounded of the secondary colours. Thus the two secondaries, orange and green, are assumed to give rise to the tertiary colour known as *citrine.* This hue is really nothing more than a yellow-grey; for its orange constituent contains yellow and red, and its green constituent yellow and blue. Subtracting equivalents of the three primaries, so as to form grey, we have, therefore, nothing but a residue of the primary yellow, to produce the whole colour-effect of the mixture of the secondaries orange and green. This residual yellow is dulled by the presence of the grey which is the product of mixing equivalents of pigments representing the three primaries. The colour complementary with citrine or yellowish-grey is violet, which, of course, supplies the blue and red which have been extinguished in the former hue.

The secondary colours orange and violet produce, when mixed together, the tertiary hue known as russet. It is really a reddish-grey. Some autumnal leaves present good examples of this colour. Its complementary is green, which supplies the yellow and blue which are wanting in russet.

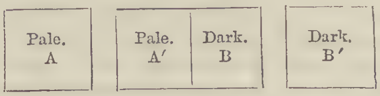
The secondary colours green and violet produce, when mixed together, the tertiary hue often called olive, but which may, perhaps, be more correctly designated slate. It is really a bluish-grey. The complementary colour is orange, which supplies the missing red and yellow constituents.

We may here name, as other and very useful tertiary hues, those known as buff, plum, and sage. Buff, or orange modified by grey, may be produced by the addition of red to citrine, or by mixing the three primaries so that yellow and red predominate. Sage-green is produced by the addition of yellow to slate-colour, or by mixing the three primaries so that both yellow and blue predominate. Plum-colour is a violet-grey produced by the addition of blue to russet, or by mixing the three primaries so that both blue and red predominate.

Numerous other tertiary hues, besides the six just named, are constantly observed in natural objects, and may be reproduced with great advantage in decorative art. It is, however, very difficult to describe the composition and character of such colours.

Contrasts of tone and of colour.—If there be the slightest difference either of tone or of colour in two contiguous or neighbouring coloured or shaded surfaces, that difference will not be seen exactly as it really exists. Under such conditions, either the retina of the eye receives an impression which does not actually reproduce the facts of the exterior phenomenon, or the message transmitted to the brain is itself modified. Whatever the exact cause, the study of the *subjective* modifications of tone and colour is one of the most important branches of our present series of lessons. We shall describe, first of all, contrasts of tone, and then contrasts of colour.

Contrasts of tone may be either successive or simultaneous. Of the first kind, we have examples in the facts that a dark-toned piece of cloth or paper looks lighter if we have immediately before been looking at a still darker piece; and that a light-toned piece looks darker, if we have immediately before been looking at a still lighter piece. The following are illustrations of the facts of the simultaneous contrasts of tones:—We first take two strips of pale-grey paper, and fix them a few inches apart towards one side of a piece of linen stretched across a window. Two similar strips are next prepared, but they are to be of a considerably darker tone. One of these is placed so as to touch one of the first strips; the other is fixed at some few inches' distance. The following sketch shows the arrangement of the strips:—



Upon steadily looking at the four sheets for a short time, it will be perceived that A′ close to B seems lighter than A, while B close to A′ seems darker than B′. The effect of contrast in altering the tone of the contiguous strips A′ and B may be further studied in this way. Make such openings in a piece of card as to divide the strips A and B each into three portions. It will then be noticed that the two nearest portions are most contrasted in tone, and the others less so in proportion to their distance from the line of contact. But the effect of contrast of tone is still better seen when a more complete series of toned strips is placed in contiguity. In such a case the effect on all the strips, save the end ones, is that of a double contrast. The second strip, or second tone, has one side of it made apparently darker by reason of the contiguity of the lighter tone of strip 1, while the other side seems lighter by the contiguity of the

darker tone of strip 3. The general result of these double contrasts is that the whole series or scale of tones presents the appearance of a number of hollows, although, in fact, the apparent hollows are perfectly flat spaces of shading or colouring. The effect is approximately represented in Fig. 14, where

Fig 14.

1 2 3 4 5 6

the real flatness of each tone of the six may be verified by covering up all the other spaces by a card. The same diagram of contrast of tone may be made more effective, by dividing a slip of card into several equal sections—say, six—by faint pencil lines, and then giving all six a light wash of Indian ink. Next, when this is dry, five sections receive a second similar wash. Afterwards the same process is repeated until the third section has received three washes, the fourth section four, the fifth section five, and the sixth section six. In carrying out the process, all sections, except those being submitted to the operation of washing, should be hid from view. Without this precaution it is difficult to secure a flat tint in each strip. If a series of pieces of grey paper of the same colour, but of different tones, are obtainable, they may be used in the construction of the same figure. They should be of equal size, and be pasted close together on a strip of cardboard; or a strip of glass or gelatine may be so arranged as to present at one end one thickness of the material, and the other end six or more thicknesses. On looking through the series, especially if a piece of white enamel glass, or a sheet of white paper, be placed behind, the effect of simultaneous contrast of tone will be clearly perceived. It is scarcely necessary to state that the tones of any particular colour may be used as well as grey to illustrate this kind of contrast. Its characteristic effect is not seen unless the contrasting tones differ considerably in intensity, and are in close contiguity or absolute contact.

Contrasts of colour are always more or less complex in character. There is, to begin with, the actual or objective difference between two colours, and then, superadded to this, we have certain subjective modifications, of an ocular or mental kind, which all contrasted colours produce. Further than this, it is rare to find any contrast of colour in which the effects of contrast of tone are not likewise present. We shall have to speak in a future lesson, and with considerable detail, of the practical results of all the circumstances which affect contrast of colours, and so now we merely introduce this subject by a few words on the successive and simultaneous contrast of colour.

If the eyes have steadily regarded some coloured object, and then look at a colourless object, that object will assume a colour complementary to that of the former, or will present an image of that object in the complementary colour. If the second object be itself also coloured, but differently from that first viewed, then the complementary colour will mingle with that of the second object, and modify its proper colour accordingly. But even a third case of successive contrast may occur. Supposing we look steadily at a series of pieces of scarlet cloth, one after another being placed before us; the eye, fatigued with the repeated calls on its perception and appreciation of scarlet, becomes incapable of estimating the series of identical specimens, and reports the last specimen to be duller than the first. The eye has become less appreciative of red, and more appreciative of the other colours. It sees less red, and more green than before. This green mixes with the red of the later specimens of cloth, dulling and modifying them. The eye may be rested and restored to its proper condition by gazing upon a piece of green cloth, when its power of appreciating red will once more return.

The simultaneous contrast of colours was first thoroughly worked out by the French chemist, Chevreul. It is the most fertile of all the laws of colour in the elucidation of the actual phenomena of contrasts, and in the suggestion of new combinations. When two coloured objects are seen at the same time, they usually mutually affect each other both in colour and tone. A yellow object, for example, placed close to a blue one, will appear as if it inclined to orange, while the blue object will seem to incline towards violet. The reason of this, on the assumption that yellow, red, and blue are the primary colours, is that the eye looking at yellow becomes less able to appreciate it, and sees the remainder of the primary colours, red and blue, that is, violet. This violet mixing with the contiguous blue colour tinges it with a faint trace of red. So with the blue object: the eye looking at the blue becomes less able to appreciate it, and sees the remaining primaries, yellow and red, or orange, the complementary of blue, which orange is imparted to the yellow, giving it a reddish hue. But blue and yellow differ much in their respective value as regards tone. The luminous and brilliant yellow becomes still more brilliant by contact with the richer and deeper blue, which itself is at the same time deepened, so that under ordinary circumstances these two colours afford a combined example of simultaneous contrast of tone and colour. But two complementary colours, such as red and green are presumed to be according to the common theory, do not modify one another's colour by contiguity. Theoretically, they contain the three constituents of white light, and the eye perceives no deficiency or excess of any coloured elements in the combination. So red and green merely enhance each other's characteristics when in contact. Thus it is with orange and its complementary blue, and with other pairs of complementary colours.

By placing strips of coloured paper together, a few of the chief phenomena of simultaneous contrast may be easily observed. We here give a list of some of the modifications of hue which coloured surfaces seem to undergo when placed in contact in pairs :—

Red	inclines to	violet.	Orange	inclines to	yellow.
Red *with* orange	,, ,,	yellow.	Orange *with* violet	,, ,,	blue.
Red	,, ,,	violet.	Yellow	,, ,,	orange.
Red *with* yellow	,, ,,	green.	Yellow *with* green	,, ,,	blue.
Red	,, ,,	orange.	Yellow	,, ,,	orange.
Red *with* blue	,, ,,	green.	Yellow *with* blue	,, ,,	violet.
Red	,, ,,	orange.	Green	,, ,,	yellow.
Red *with* violet	,, ,,	blue.	Green *with* blue	,, ,,	violet.
Orange	,, ,,	red.	Green	,, ,,	yellow.
Orange *with* yellow	,, ,,	green.	Green *with* violet	,, ,,	red.
Orange	,, ,,	red.	Blue	,, ,,	green.
Orange *with* green	,, ,,	blue.	Blue *with* violet	,, ,,	red.

TECHNICAL DRAWING.—XVI.

DRAWING FOR MACHINISTS AND ENGINEERS.

Fig. 172.—This study is intended as an exercise in the use of the set-square of 60°.

Having constructed the containing rectangle, draw diagonals by means of the set-square resting on its shortest side on the T-square. All lines drawn against the hypothenuse of the set-square in this position will be at 60° to the horizontal lines and at 30° to the perpendiculars.

Now divide the base into the required number of equal parts, and draw lines from them parallel to both diagonals. This is done by turning the set-square. These lines will cut the perpendicular sides of the containing figure, and from the points thus obtained lines parallel to the diagonals may again be drawn as before.

To test the correctness of your work as you proceed, (1) Draw the horizontal line A B, which should pass through all the intersections at that height.

(2.) Draw the perpendicular C D, which should pass through all the intersections at that distance from the side.

(3.) Join any two of the points on a line drawn, as A B, and on E F construct two equilateral triangles; the apex of the one should be on the intersection G, and the other at H.

If the drawing does not fulfil all these conditions, there is something incorrect in the construction; and as the error would cause all the work based upon this original figure to be inaccurate, it is advisable to rub it completely out and start afresh. The most economical plan is, therefore, to work with the utmost care in the early stages, on which all the subsequent operations are based.

Fig. 173 is another design for a cast-iron grating, as an application of the foregoing study.

Having carried your work up to the stage shown in the last lesson, it becomes necessary to mark the width of the cross-bars.

Now in Fig. 170 this was done by setting off half the required thickness on each side of the intersection; but it will be evident that in the present instance this would not answer the purpose, as the lines intersecting are not at right angles to each other, and therefore the measurement set off on them would not give the correct width. Therefore, at any point (as *a*) draw a line at right angles to one of the cross-lines, and on this, on each side of the intersection, set off the half-width of the bars—viz., *b*, *c* —and through these points draw the required lines cutting the cross-lines in *d* and *e*. This length, therefore, may be set off from each of the intersections, and the required widths of the bars will thus be obtained. The centres for the circles are, of course, the intersections of the primary lines.

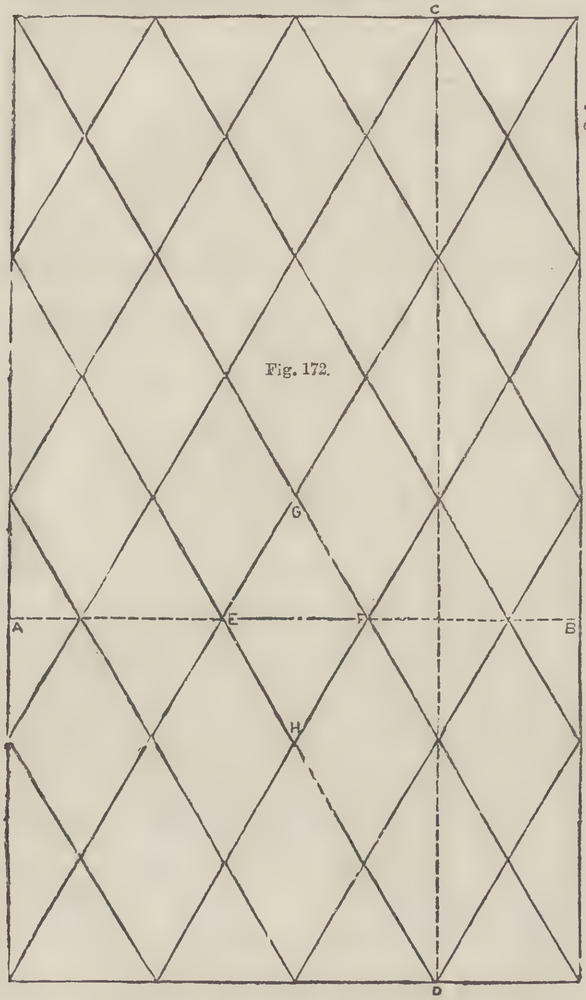


Fig. 172.

Figs. 174, 175, 176, 177.—These figures are simply intended to give practice in drawing concentric circles. The greatest care is necessary in this operation. The compass should be held loosely between the forefinger and thumb; the pressure on the steel point should be so very little that scarcely a mark is made on the paper. If by carelessness or pressure the paper is penetrated, the hole will be made larger as each circle is drawn, and of course the centre becomes no longer true. Thus the circles will not be parallel to each other, nor will the curve on ending meet the starting-point.

As concentric circles are of constant occurrence in mechanical drawing, it is important that the student should acquire the power of drawing them with the utmost precision and facility. The pencil-leg should be allowed to trail over the paper, and where numerous concentric circles are required it will be found in many cases unnecessary to pencil them; the radius of each may be merely marked on a line drawn through the centre, and the circles themselves can then be at once drawn in ink.

If a large circle is to be drawn, the inking-leg of the compass should be bent at the joint to allow of both the nibs of the pen touching the paper. If this is not done, the outer edge of the circle will be ragged. For small circles, bow-compasses are necessary. These, which have been already described (page 12), are small compasses with a neat handle at the top, by means of which they may be twirled round between the finger and thumb with the greatest ease. The best kind are made with joints in both legs, by means of which the steel point and the pen or pencil can be made upright, and thus far better work is secured. For still smaller circles "spring-bows" are used. These are very small and refined instruments, which open by means of a spring instead of a joint, and are regulated by a screw; they are

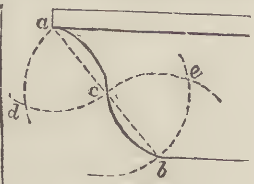


Fig. 182.

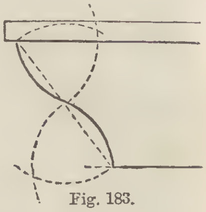


Fig. 183.

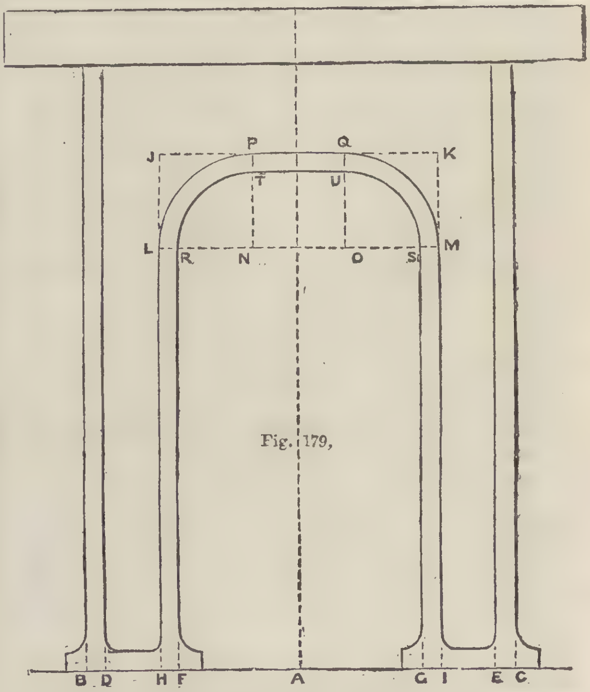


Fig. 179,

only sold in the better class of boxes, but a set of bow-compasses (three) can be purchased in separate small cases.

Fig. 178.—This study is designed to afford practice in joining arcs. The first line to be drawn in this case is the horizontal. On this describe a semicircle, A B. From the point where the semicircle meets the straight line (viz., B), set off the radius viz., B C), and from C describe the next semicircle on the opposite side of the line, carefully observing that the semicircle starts accurately from B, and that the joint is effected without any thickening, the curves running into each other so as to form one smooth wave-line. When the student can accomplish this, the drawing of a wave-line of a given breadth may be attempted.

Having drawn the centre line as above, set off as the radius on each side of B half the required breadth—viz., B E and B F; then with radius extending from the centre to each of these points in turn describe the semicircles required. Joining curves to straight lines occurs frequently in mechanical drawing, and this is therefore made the subject of the following study.

Fig. 179.—The object here represented is a portion of the framing of a small "table engine."

Having set off from the centre line, A, the half-width of the framing, A B and A C, erect perpendiculars. Draw the horizontal surface at the top and the edging D, E.

Now set off from A the distances F and G, for the width of the opening, and from A set off also A H and A I, so that F H and G I may be equal to B D and E C, the edging of the framing.

From H I G F erect perpendiculars, and at J K and L M draw horizontal lines.

From L and M set off L N and M O equal to L J or M K, and at N and O erect perpendiculars, cutting J K in P and Q.

From N and O, with radius N L or O M, describe quadrants joining L P and M Q. From N and O describe quadrants, with radius N R or O S, cutting N P and O Q in T and U.

Join P Q and T U, which will complete the framing.

The manner in which the curves at the foot of the framing are obtained being precisely similar to those above, no instructions concerning them are deemed necessary.

Observe.—When curves are to be joined to straight lines, *draw the curves first*, as it is easier to draw a straight line to meet a curve than the reverse.

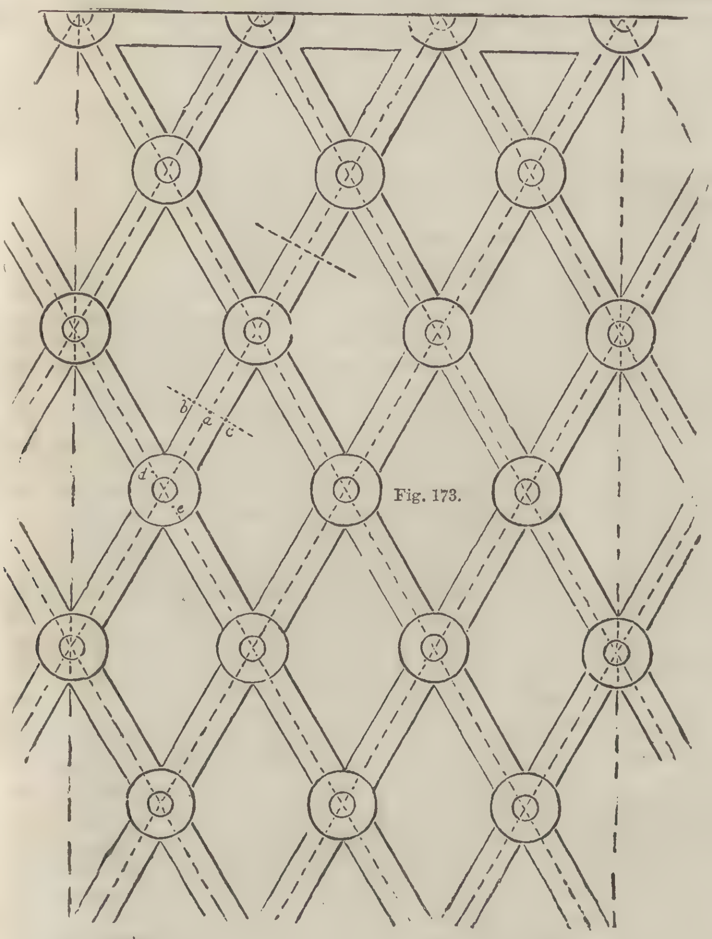


Fig. 173.

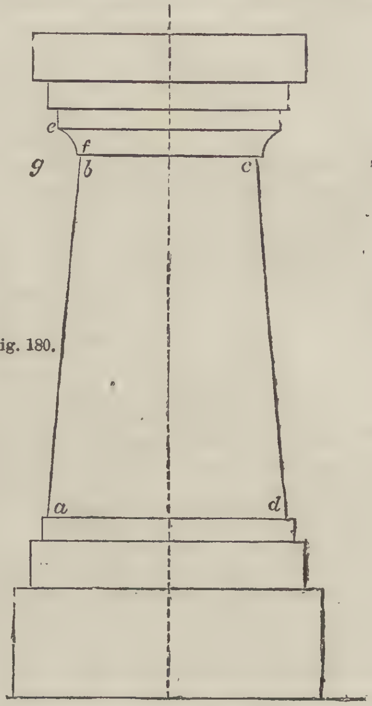


Fig. 180.

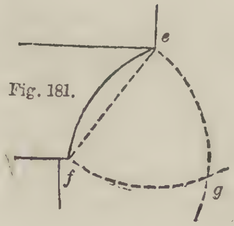


Fig. 181.

Fig. 174.

Fig. 175.

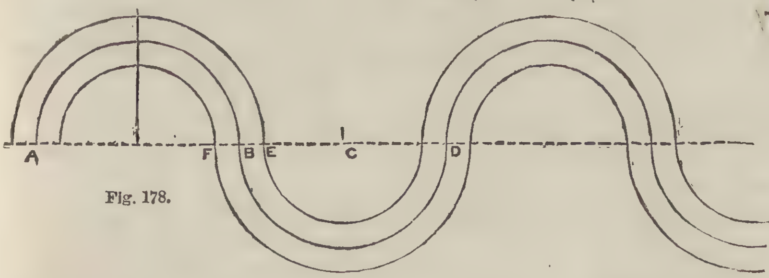


Fig. 178.

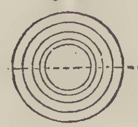


Fig. 176.

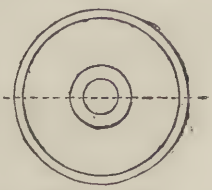


Fig. 177.

Fig. 180.—This is an elevation of the pillar supporting the "governor," from the same small engine. It is supposed that but little trouble will be found in drawing this figure, as far as the straight portions of it are concerned.

Draw the ground line and central perpendicular, on which set off the heights for the horizontals. When these have been drawn, the widths are to be set off from the centre line. The points a b and c d having been joined, it only remains to describe the curve at e f and that on the opposite side. This curve is the arc which is formed by using the apex of an equilateral triangle as the centre, and the side of the triangle as the radius. This part of the drawing is worked out on a large scale in the next example (Fig. 181).

From e and f, with radius e f, describe arcs cutting each other in g; then from g, with the same radius, describe the arc e f as required.

Fig. 182 is the Cyma Recta moulding, and Fig. 183 is the Cyma Reversa. Both of these are of frequent occurrence in the

framing of machinery, and the mode of constructing them is therefore introduced here.

Draw a line between the points which are to be connected by the curve, as *a b* (Fig. 182), and bisect this line in *c*. From *a*, *c* and *c*, *b* describe arcs cutting each other in *d* and *e*; these will be the centres for the two parts of the curves, which must glide smoothly into each other at *c*. The form of curve may be varied by moving the point *c* either higher or lower, or taking a shorter or longer radius with which to describe the arcs.

AGRICULTURAL DRAINAGE AND IRRIGATION.—VI.

By Professor WRIGHTSON, Royal Agricultural College, Cirencester.

COST OF DRAINAGE, ETC.

LAND drainage under ordinary circumstances can hardly be spoken of as a very complicated process. The reasons which account for its marvellous effects, the changes it induces in the soil, the discussion as to the proper depth, distance, and direction of the drains, and the practical advantages which follow its adoption, are all fertile subjects. The mere description of the process of laying the pipes, however, need not detain us long. We have already devoted some attention to this portion of the subject, and it now remains for us to consider some difficulties which the practical drainer will encounter. Where the land is very wet, it is occasionally difficult to keep the trench open, in which case support must be given to the sides by boards and struts until the tiles are laid. Sometimes a quicksand is met with, upon which it is impossible to lay tiles, as they would speedily sink out of regular line. Under such circumstances, a layer of straw (according to Mr. Wilson, of Edington) or a narrow board must be used in order to give support to the tiles until they have time to act on the surrounding mass of soil, and render it dry and firm.

Tree and hedge roots are another source of danger. In order to avoid this, no drain should be laid nearer than five or six yards to a fence, unless special precautions are taken for preventing the entrance of root-fibres. Thorns are sometimes placed over the tiles in such drains to prevent this occurrence, and, in other cases, close-fitting collars are used at every joint so as to secure them from the entrance of roots.

It is occasionally necessary to carry a drain across a water-course, and when this is required it may be passed underneath with the assistance of a few feet of iron piping.

Another difficulty frequently presents itself in obtaining a good outfall. Ditches which receive drainage water ought to be strengthened and deepened so as to offer the least possible resistance to its passage. Where the land to be drained is situated on a river-bank, it is sometimes difficult to contrive a suitable outfall for three or four feet drains. In such cases the main drain must be run parallel with the stream such a distance as to ensure an outfall for the higher-lying land. Landfast stones and rock also are frequent obstructions in cutting drains, but this is a difficulty which gives way before extra labour. If the rock is of a porous character it may occasionally be made use of as a vent for surface water. This plan is frequently followed in chalk and other districts where the nature of the soil will allow of it. The water is brought by ordinary drains to a low point or focus, where a well is sunk down into the rock, and thus the water is discharged into the great reservoir which underlies the formation.

The complete aëration of the soil is one of the principal functions of drains. It is, therefore, by no means a matter of surprise that the idea of "air drainage" should have been maintained strongly by many agriculturists. All draining, so far as it admits air, and cannot act unless air is admitted, is air drainage, but the advocates of this system wish to go further. They found an able exponent in the late Mr. S. Hutchinson, agent to the late Earl Brownlow. An idea of this method may be best obtained by reference to Mr. Hutchinson's experiments as recorded in Vol. IX. of the *Royal Agricultural Society's Journal*. He there makes the following statement: "The field to which I refer is in the occupation of Mr. Strafford, of Marnham, near Newark-upon-Trent, and consists of ten acres of strong loamy soil, resting upon a clay subsoil. It was underdrained by Mr. Strafford in 1843, by twenty-five parallel drains, two feet deep and five yards apart, each discharging into a covered outfall at the bottom of the field. In the autumn of 1846 it occurred to me that this being a shallow-drained field, presented a good opportunity for experiment. I divided it into five compartments,

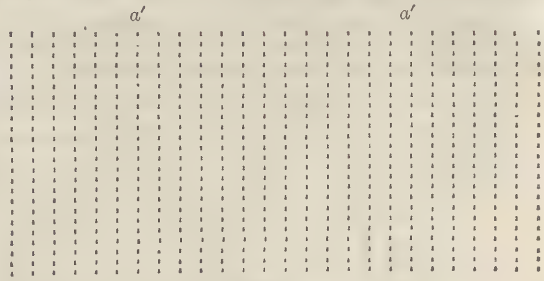


Fig. 11.

(see Fig. 11), each containing five of the drains. With the two outside and the centre compartments I did not interfere. Into the two other compartments I introduced what I called an air-drain, *a′ a′*, across the upper ends of the five drains, in each case, to join them together. I then connected the air-drain so cut with the adjacent open ditch at the top of the field, in order to increase the natural circulation of air through the ordinary drains." This experiment was successful, and subsequently both Mr. Strafford and Mr. Hutchinson were struck with the benefit following the introduction of the air-drains, when the land under their influence was compared with the neighbouring compartments not so treated. With a view to test the accuracy of these observations, the produce per imperial acre was accurately ascertained, both in wheat and turnips, and the result showed a palpable advantage in the *air-drained* plots. The prescribed method is exceedingly cheap, and may be resorted to without appreciably increasing the expense. Upon some soils an air-drain may be required in order to facilitate the egress of water; in others the porous character of the soil will allow a sufficient circulation of air without any additional help.

We now approach the consideration of the cost of drainage. This will vary with the expense of digging the trenches, their depth, the distance between them, and the price of tiles. The cost of digging three-feet drains through homogeneous clay soils is often estimated at one penny per linear yard, but where stones and rock occur this price may be indefinitely increased.

The distance between the drains resolves itself, so far as cost is concerned, into a mere question of the numbers of rods or chains per acre; and the price of tiles is very dependent upon that of coal. Where this is abundant, 2-inch tiles (internal diameter) may be obtained at from 17s. to 20s. per thousand, and three-inch tiles at about 30s. per thousand. The following tables, taken from Wilson's "British Farming," embody much valuable information upon several of the points touched upon.

TABLE SHOWING THE NUMBER OF RODS OF DRAIN PER ACRE AT GIVEN DISTANCES APART, AND THE NUMBER OF PIPES OF GIVEN LENGTHS REQUIRED PER ACRE.

Intervals between the drains.	Rods per acre.	12-inch pipes.	13-inch pipes.	14-inch pipes.	15-inch pipes.
18 feet	$146\frac{2}{3}$	2420	2234	2074	1936
21 ,,	$125\frac{5}{7}$	2074	1915	1778	1659
24 ,,	110	1815	1676	1555	1452
27 ,,	$97\frac{6}{7}$	1613	1489	1383	1290
30 ,,	88	1452	1340	1244	1161

From the following table we learn the expense of draining land will, under ordinary circumstances, vary from £5 to rather more than £8 per acre, according to the distance between the channels. There are, however, other important elements connected with the materials used for forming the drains, the depth of the drains, and the tenacity or rockiness of the soil. With these ever-varying conditions, the cost may easily exceed or be less than the above estimates. Thus Mr. Stephens gives a list of prices ranging from £2 7s. 6d. to £9 10s. per acre. The first case was that of a soil described as overlying irregular beds of gravel or sand, and irregular open strata, the material used being broken stones. In such a case the distance between

the drains might be increased easily to forty feet with good effect. Contrasted with this minimum expenditure, we have the high figure above given, in which the soil was described as "hard till" or clay, when it was found requisite to place the drains ten feet apart, and where stones were used as the material.

TABLE SHOWING THE COST OF DRAINING PER ACRE AT VARIOUS INTERVALS BETWEEN THE DRAINS.

	18 feet apart.	21 feet apart.	24 feet apart.	27 feet apart.	30 feet apart.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Labour—cutting and filling at 6d. per rod	3 13 4	3 2 10	2 15 0	2 8 11	2 4 0
Material—pipes for minor drains 18s. per 1,000 . .	2 5 9	1 19 2	1 14 3	1 10 6	1 7 5
Haulage 2 miles and delivery in fields at 2s. 6d. per 1,000 .	0 6 4	0 5 5	0 4 9	0 4 3	0 3 9
Pipe-laying & finishing at 1d. per rod.	0 12 2	0 10 6	0 9 2	0 8 2	0 7 4
Superintendence—foreman . .	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0
Extra for mains .	0 2 0	0 2 0	0 2 0	0 2 0	0 2 0
Iron outlet pipes and masonry, and extra labour . . .	0 1 6	0 1 6	0 1 6	0 1 6	0 1 6
Total . .	7 6 1	6 6 5	5 11 8	5 0 4	4 11 0
Add for collars if used . . .	1 2 10	0 19 7	0 17 1	0 15 3	0 13 8
£	8 8 11	7 6 0	6 8 9	5 15 7	5 4 8

The Marquis of Tweeddale gives the expense of tile-draining as varying from £4 to £10. The lower price is for cutting two-feet drains thirty feet apart at a cost of ½d. per yard, and the higher figure is for draining three and a-half feet deep, fifteen feet between the drains, and at a cost of more than 1d. per yard (Stephens). Draining by means of the mole plough may be accomplished at a cost of from £1 per acre, according to a recent report upon Mr. Ruck's farm, at Braydon Manor, to £1 8s. and £1 10s., according to the nature of the soil, and the depth and distance. When, however, circumstances vary so widely, it is a difficult matter to fix any definite limit to the expense, almost every field requiring a different treatment to the last, and each case having its own special requirements with regard to depth, distance, and cost of labour.

The effect of drainage in increasing the produce is, in some cases, exceedingly marked. Instances are not wanting in which the agricultural value of the land is entirely owing to this improvement. In very many cases one quarter extra per acre of wheat, and a proportional increase in the yield of other crops, is looked upon as the advantage which may be expected. Again, looking at the benefits of land drainage from a general point of view, we find farmers willing to pay 6 per cent. upon money thus expended by their landlords, and at the end of the lease this per-centage is incorporated in the ordinary rent-charge, thereby showing that the improvement is looked upon as permanent. Among the best examples of improvement are those collected by Mr. Stephens in the "Book of the Farm." There we are told that in the case of land belonging to Mr. Dalrymple of Cleland, Lanarkshire, one field of eighteen acres cost £5 9s. per acre to drain. Previously this field had been occupied with whins and rushes, and had been let for 12s. per acre; but after draining, the wheat off one portion of it brought £13 per acre, the potatoes off another part £15 15s. per acre, and the turnips off the remainder £21 per acre. Mr. James Howden, Wintonhill, East Lothian, asserted years ago that, although drains should cost as much as £7 per acre, yet on damp heavy land thorough drainage would repay from 15 to 20 per cent. upon the outlay. A farmer in Lanarkshire, who thoroughly drained one-half of a four-acre field, and left the other half undrained, planted the whole field with potatoes. From the drained half he realised £45, whilst the undrained half only realised £13 per Scotch acre. It appears almost unnecessary to multiply instances. We conclude by citing the results obtained on the Teddesley Hay Estate, the property of Lord Hatherton, where, after an expenditure of from £3 10s. to £4 per acre, the rental value of the land was increased in one case from 10s. to 27s. per acre, in another from 10s. to 35s. per acre, in a third from 16s. to 33s., and in a fourth from 8s. to 22s. per acre. Such examples, although matters of fact, may possibly mislead unless it be remembered that the ordinary result is much less striking, and that the more modest but satisfactory return first spoken of will be a more usual measure of the direct advantages derived from land drainage.

No one now denies the advantage of draining arable land, although some persons hold that it is possible to overdrain even this. With regard, however, to pastures, there has been a considerable amount of discussion, many farmers considering that the amount of grass is diminished by the operation. Such seasons as 1868 and 1870 are well calculated to try the truth of such opinions: it was, therefore, exceedingly judicious in Mr. J. C. Morton, at the close of 1868, to request answers from correspondents in various parts of England upon the results, during the long-continued drought, of drainage upon pastures. In answer to the query, "Are there instances known to you of differences, as regards productiveness, during so dry a season, between drained and undrained land either arable or pasture?" Mr. Paget, of Ruddington, "confesses that where the land had been very recently drained, and consequently the grasses proper to dry land were not fully established, they did not afford quite so much 'keep' as the corresponding undrained land; but as soon as the rain fell in August, the advantage was on the side of the drained land. Those meadows which had been long drained had the advantage throughout." This is an instructive case, and explains why, in some cases, drainage has temporarily lowered the yield of grass upon pasture lands. Mr. Wortley, of South Collingham, Newark, says, "I must say that, according to my experience, there is some foundation for the popular belief that a certain kind of grass land is injured by under-draining; that is to say, the inferior plants which previously made a show, if they did little more, are destroyed by the drainage, and they are very slowly replaced by better, if the land is left to itself. With such exceptions, however, my belief has always been that the draining of wet land, whether arable or grass, increases the productive power, even in such seasons as the last." Mr. James Rawlence also says, "I quite think with you that more corn or grass have been grown on drained than on undrained land, except on grass land which had been drained the previous autumn, in which case the aquatic plants all died out from the long drought and heat, and the more nutritious grasses had not time to fill up their places." These concurrent testimonies to the effect of drainage upon grass lands are very conclusive, and reconcile apparently contradictory observations, it being evident that although the ultimate effect of drainage upon grass land is beneficial, yet there is a period of trial between the dying out of sedges and water-grasses and the prevalence of a sweeter and better herbage.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—IV.

DEFINITIONS CONCERNING POLYGONS.

All figures having more than four sides are called polygons, and are distinguished by names denoting the number of their sides and angles—thus:

A Polygon of 5 sides is called a Pentagon.
" 6 " " Hexagon.
" 7 " " Heptagon.
" 8 " " Octagon.
" 9 " " Nonagon.
" 10 " " Decagon.
" 11 " " Undecagon.
" 12 " " Duodecagon.

When all the sides of a polygon are equal, and all its angles equal, it is called *regular*.

When they are not equal, the polygon is said to be *irregular*.

By drawing lines from the angles of a regular polygon to the centre, the figure may be divided into as many triangles as the polygon has sides. In the regular hexagon these triangles will be *equilateral*, but in all other regular polygons they will be isosceles.

The methods of constructing the various polygons having been given in "Lessons on Geometry" in The Popular Educator,

it is only necessary in this place to give one or two, in order to show their application in mechanical drawing.

To inscribe a regular pentagon in a circle, by a special method (Fig. 40).

Draw the diameter A B, and bisect it, or divide it into two equal parts in O. At O erect a perpendicular, O C. Bisect O A in the point D, according to the method indicated in the figure.

From D, with radius D C, describe an arc cutting A B in E.

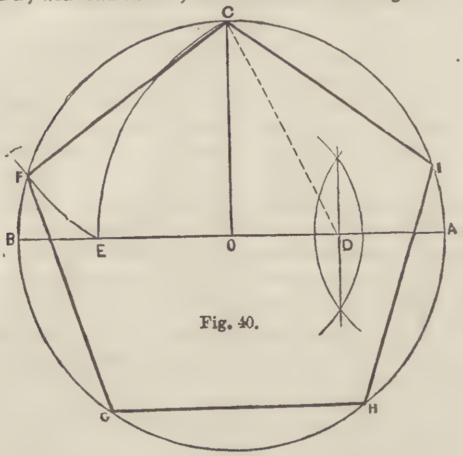


Fig. 40.

From C, with radius C E, describe an arc cutting the circle in F.

Draw C F, which will be one side of the pentagon.

Set off the length C F around the circle in the points G, H, I.

Draw lines F G, G H, H I, and I C, which will complete the figure.

Application of the foregoing principle in the construction of Gothic tracery (Fig. 41).

Draw a circle, divide it into five equal parts, and draw the radii O A, O B, O C, O D, O E. Bisect one of the radii, and set

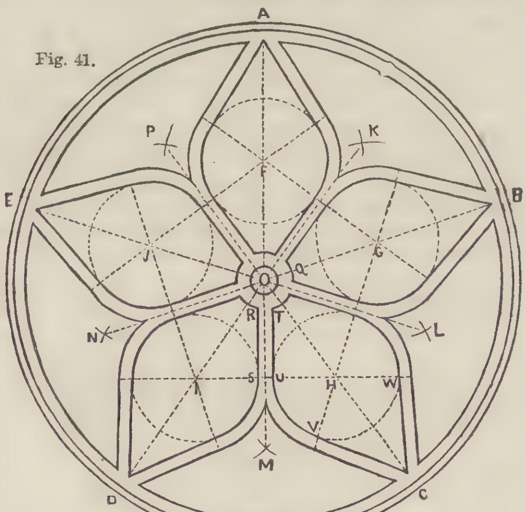


Fig. 41.

off the half on each of them in the points F, G, H, I, J. Join these points, and a regular pentagon will be formed.

Bisect the sides of this pentagon by the lines O K, O L, O M, O N, O P.

Draw a small circle in the centre, and another, Q, concentric with it.

From Q to the sides of the pentagon draw lines parallel to O K, O L, etc., at a small distance on each side of them—viz., R S, T U, etc.

Produce the sides of the pentagon indefinitely from F, G, H, I, J, and with radius H U describe circles cutting the produced sides of the pentagon in V W and the corresponding points.

Draw V C, W C, and similar lines from the other circles, and the remaining lines will be parallel to, and concentric with, those already drawn.

To construct a regular hexagon on the given line A B (Fig. 42).

From A and B describe arcs cutting each other in O.

From O, with radius O A or O B, describe a circle.

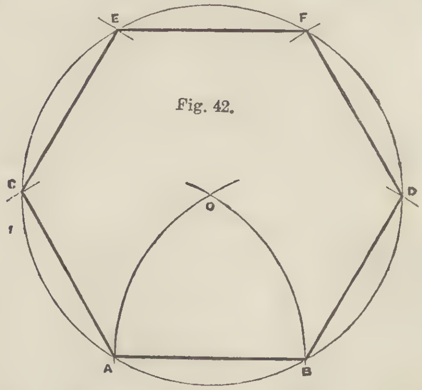


Fig. 42.

The radius with which a circle is struck will divide it into six equal parts; therefore set off the length O A, which is equal to A B, around the circle—viz., C D E F.

Join these points, and a regular hexagon will be formed.

To inscribe a regular hexagon in a circle.

Find the centre of the circle, set off the radius around it, and join the points.

Example 1 of inscribing a hexagon in a circle.—To draw a simple fly-wheel (Fig. 43).

Draw the circles A and B, representing the outer and inner edge of the rim.

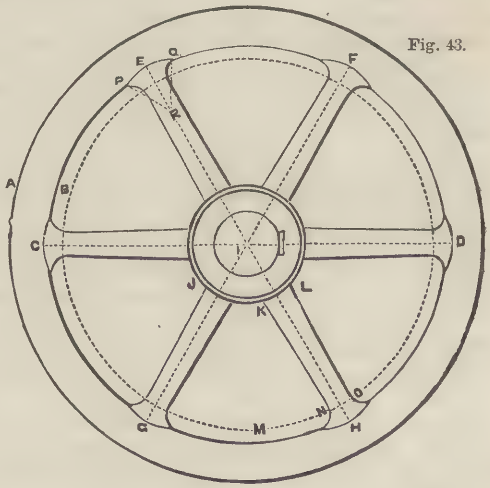


Fig. 43.

Divide the circle B into six equal parts, and draw the diameters C D, G F, E H.

Next draw the circles I and J, representing the end of the shaft and the boss, or central part of the wheel; the small parallelogram at the side of the inner circle represents the "key," by which the wheel is held on the shaft.

On the edge of the boss set off equal distances, K L.

Draw the circle M, and on it, on each side of the radii, set off distances rather less than K and L—viz., N and O.

Draw the sides of the arms, K N and L O, etc.; and with any convenient radius describe the small arcs connecting the arms with the rim at N and O.

The length P Q set off from P and Q on the radius, will give the point R, which is the centre for striking the arc, caused by the elliptical arm meeting (called *penetrating*) the elliptical rim.

Example 2 of the application of the hexagon in mechanical drawing (Fig. 44).

In this drawing of a nut and bolt, the plan—that is, the appearance it would have if your eye were directly over it, and you looked down upon it—is to be drawn first.

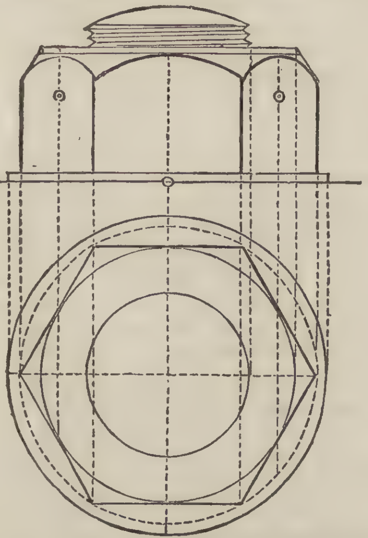


Fig. 44.

The two largest circles being described, the inner one is to be divided into six equal parts, and a hexagon inscribed in it.

Perpendiculars drawn from each of the angles of the hexagon will give the projection of the widths of the sides of the nut.

Within the equilateral triangle, A B C, *to inscribe six equal circles* (Fig. 45).

Draw the lines B D, A F, and C E, bisecting the sides and angles of the triangle, and intersecting each other in O.

Bisect the angle O A E, and the point (G) where the bisecting line cuts C E, will be the centre of one of the three isosceles triangles, into which the equilateral triangle has been divided.

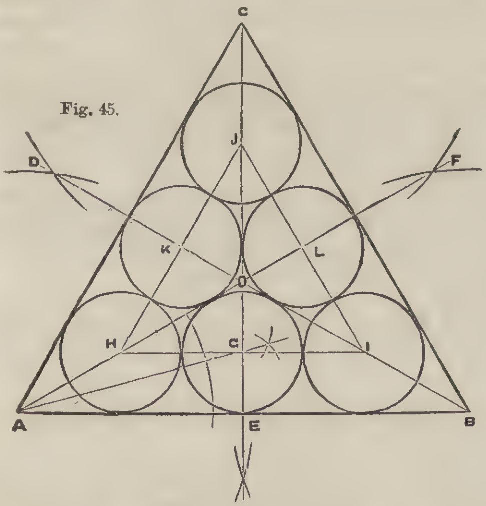


Fig. 45.

Through G draw H I parallel to A B, and from H and I draw H J and I J, cutting B D and A F in K and L.

From G H I J K and L, with radius G E, draw the six circles.

To inscribe three equal circles in a circle (Fig. 46).

At any point, as A, draw a tangent, and A G at right angles to it. From A, with radius O A, cut the circle in B and C.

From B and C draw lines through O, cutting the circle in D and E, and the tangent in the point F (and in another not given here, not being required). Bisect the angle at F, and produce the bisecting line until it cuts A G in H.

From O, with radius O H, cut the lines D C and E B in I and J.

From H, I, and J, with radius H A, draw the three required circles, each of which should touch the other two and the outer circle.

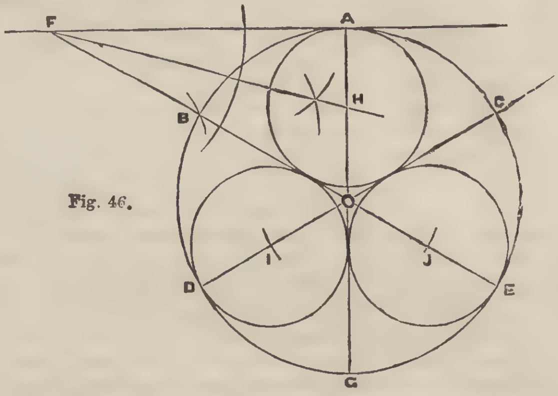


Fig. 46.

To inscribe in an equilateral triangle, A B C, *the three largest circles it will contain* (Fig. 47).

Draw A G, B F, and C E, bisecting the angles and sides of the triangle, and intersecting in O.

Bisect the right angle A E O.

Produce the bisecting line until it cuts A G in H.

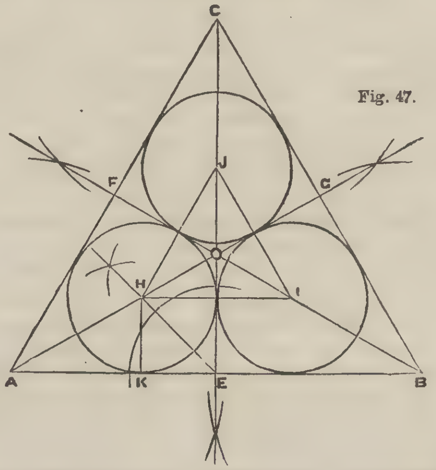


Fig. 47.

Draw H I parallel to A B, H J parallel to A C, and I J parallel to B C.

From H, I, and J, with radius H K, draw the three circles, each of which should touch the other two, and two sides of the triangle.

NOTABLE INVENTIONS AND INVENTORS.

V.—CLOCKS AND WATCHES (*concluded*).

BY JOHN TIMBS.

CLERKENWELL has long been noted as a clock-making parish. The most extensive establishment here has workshops for every branch of manufacture: as the brass-casting, the wheel and pinion cutting, the case-making, and the movement-making. Wooden clocks are made on the confines of the Black Forest, by peasant families—the export of clocks from Baden alone amounting to £1,000,000 sterling. Of American clocks, in New Haven 50,000 brass eight-day clocks are made in a year at one factory; the wheels and plate-holes are all stamped, and the maintaining power is a spring, in place of the gradual fall of a heavy weight. In electrical clocks, the indicator has a clock-face and an index, or hand, and the communicating disc is moved round by the oscillation of a pendulum, kept going by electricity; thus one clock, by a wire, communicates its own time to any number of clocks at any distance, kept in perfect unison by the action of only one pendulum. Horological electricity also drops time-balls, fires time-guns, and exhibits an hourly signal from the

parent electro-magnet clock at Greenwich Observatory, to correct any error in the great clock at Westminster. Illuminated clocks date from the "fire-clock" of Martinelli, in 1663, and in an old German work we find designs for illuminated dials; in one the light is placed behind a transparent dial and opaque figures, which are reflected, much magnified; in another, the light issuing from a lantern is so arranged as to fall on, and be continued to, the dial of a clock.

It is curious to find, in the year 1869, the good citizens of Beauvais placing in its cathedral a monumental clock, composed of 14 different movements, and 90,000 pieces (weighing 35,000 lb.), and costing £5,000. The body of the clock is 36 feet high, of carved oak; it has a figure of the Supreme Being, and the twelve apostles, in enamel; the main dial (there are 50 in all) has a figure of the Saviour—the largest enamel existing. The pendulum weighs nearly 1 cwt., and is moved by a steel ball weighing but the thirty-second part of an ounce, this movement impelling the fourteen others. The other dials indicate days of the week, movements of the planetary bodies, sunrise and sunset, seasons, signs of the zodiac, duration of daylight and night, saints' days, months, phases and age of the moon, time at principal cities, solstices, movable feasts, age of the world, year of the century, bissextile years, longitudes, tides, eclipses, etc.

In the seventeenth and eighteenth centuries several very curious clocks were constructed. Among these were Grollier's model of a ball ascending and descending inclined planes, spiral grooves, and others swallowed by serpents; lizards ascending columns, with the hours marked on them, and mice moving on a graduated cornice. The "invisible clock" at Vauxhall Gardens, in 1822, is thus explained:—"An hour-hand pointed to the hours on a transparent dial, without visible connection with mechanism. This was effected by having two pieces of glass placed together, the hand being fixed in the centre of one of them, which, turning round once in twelve hours, by motion produced at a tangent, pointed to the hours marked on the other piece of glass, which was immovable."

Amongst the uses of time-keepers we find that by means of a clock, the Danish astronomer, Roemer, discovered that the eclipses of Jupiter's satellites took place a few seconds later than he had calculated, when the earth was in that part of its orbit the farthest from Jupiter. Speculating on the cause of this phenomenon, he concluded that light was not propagated instantaneously, but took time to reach us; and from calculations founded on this theory, light has been discovered to dart through space with a velocity of about 192,000 miles in a second; thus the light of the sun takes eight minutes to reach the earth. Professor Airy has ascertained the variation of gravity at the surface and interior of the earth, by descending to the bottom of a deep mine, and the result of his computations is, "supposing a clock adjusted to go true time at the top of the mine, it would gain $2\frac{1}{4}$ seconds per day at the bottom; or it may be stated thus: that gravity is greater at the bottom of a mine than at the top, by $\frac{1}{19190}$th part."

Time-pieces with springs as the maintaining power (and now called watches) were imperfect machines, going with even less precision than an old clock. They had only an hour-hand, and most of them required winding twice a day. A watch differs from a clock (says Dr. Arnott) in having a vibrating wheel instead of a vibrating pendulum; and as in a clock gravity is always pulling the pendulum down to the bottom of its arc, which is its natural place of rest, but does not fix it there, because the momentum acquired during its fall on one side carries it up to an equal height on the other—so in a watch, a spring, generally spiral, surrounding the axis of the balance-wheel, is always pulling this towards a middle position of rest, but does not fix it there, because the momentum acquired during its approach to the middle position from either side carries it just as far past on the other, and the spring has to begin its work again. The balance-wheel, at each vibration, allows one tooth of the adjoining wheel to pass, as the pendulum does in a clock; and as a spring acts equally well, whatever be its position, a watch keeps time whether carried in the pocket or in a moving ship. In winding up a watch, one turn of the axle on which the key is fixed is rendered equivalent, by the train of wheels, to about 400 turns or beats of the balance-wheel; and thus the exertion, during a few seconds, of the hand which winds up, gives motion to twenty-four or thirty hours.

The invention of the coiled spring in the watch dates from the close of the fifteenth century. It is claimed for Nuremberg, then famous for watches, but the priority is much disputed. Their introduction into England is equally uncertain. The watch of Abbot Whiting, dated 1536, is of accredited antiquity; and Count D'Albanne's silver watch, of English workmanship, is dated 1529. Henry VIII. had a watch that went for a week; Anne Boleyn possessed another, as well as a small gilt clock, now in Windsor Castle. Edward VI. had, in 1542, a "watch of iron." Mary Queen of Scots possessed a death's head and a skull watch; one in a case of crystal, coffin-shaped; and another in which a piece of catgut supplied the place of a chain; but all these were foreign watches. Queen Elizabeth had a large collection of watches. A watch was found upon Guido Fawkes; and of this period is a curious oval-shaped watch in a silver case, ornamented with mythological figures. The English watchmakers of the City of London were incorporated in 1631. In 1635 the value of a brass watch was 40s. Charles I. possessed several watches. In 1658 was constructed the spiral, or pendulum-spring, invented by Dr. Hooke and improved by Tompion. Next, Juare, by applying the pendulum-spring, added (to the hour-hand) minute-hand and wheel-hand. He also added the repeating movement in watches; one of the first was presented by Charles II. to Louis XIV. of France. Juare also made repeating watches for James II. and William III. From 1698 all makers were compelled by law to put their names on their watches. In 1724 was invented the horizontal escapement by Graham, who also invented the mercurial compensation-pendulum. Graham's escapement has been superseded by the duplex, and more recently by the lever, which is the dead-beat escapement applied to a watch. At the beginning of the last century was invented jewelling the pivot-hole of watches, to prevent friction. Next, John Harrison, by his famous chronometer, discovered the longitude, for which he received from Parliament £20,000. Among his other improvements, are the gridiron pendulum and the expansion balance-wheel—the one to equalise the movements of a clock; the other, those of a watch, under all changes of temperature, by employing two different metals to form the rod of the pendulum and the circumference of the wheel, so that the contraction of the one exactly counterbalances the expansion of the other. Another of Harrison's inventions is the going fusee, by which a watch can be wound up without interrupting its movement. A time-keeper of greater simplicity than Harrison's was that of John Arnold, for which he and his son received the Government reward of £3,000; the extreme variation of this machine in twelve months has been thirty-seven-hundredths only. Arnold also made the smallest repeating-watch ever known, for which George III. presented him with 500 guineas. The next improver of the chronometer was Thomas Earnshaw; and in this state it has remained for the last ninety years with scarcely any alteration.

Among the celebrated French watchmakers was Breguet, who paid some of his workmen thirty francs a day, and none less than a napoleon. He invented the touch watch, by which a spring touched at any time struck the hour and minute; one cost the Duke of Wellington 300 guineas.

About ten years ago, it was maintained that our common watch is, in many of its parts, a very ill-constructed machine. The train of wheel-work, which transmits the motion of the mainspring, for example, is contrived on faulty principles, and the long-used methods and engines were alike condemned. Mr. Dent has stated that every watch consists of at least 202 pieces, employing, probably, 215 persons, distributed among 40 trades—to say nothing of the tool-makers for all of them. It is next maintained that if we were then materially to alter the construction of the watch, all those trades would have to be re-learnt, new tools and wheel-cutting engines would have to be devised, and the majority of the workmen to begin life again. During this interval, the price of the instrument, it is asserted, would be enormously advanced.

Watch-making in England suffers much from overstrained competition; the annual importation of gold watches from Switzerland is about 35,000; while the total number of all kinds produced at home is but 26,000.

In America watches are manufactured on a large scale by aid of machinery. We read of a manufactory with 250 hands, more than half of whom are females. The stamps and dies are

cut by steam machinery, by which are effected the processes, also, of hardening and forming the barrels and chambers, coiling and fastening the mainsprings, gearing-wheels, and cutting their teeth; shaping pinions and axles, cutting escape-wheels, trimming and marking the porcelain dials, drilling and shaping the jewels, and adjusting and fitting together the various parts.

It has been confidently stated that the result of the introduction of machinery into the watch-making trade is already to be seen in the comparatively low price at which that necessary article is to be obtained; but hitherto the great drawback has been that machinery was unable to compete with hand-work in the extremely delicate manipulation of the watch. The difficulty, however, is stated to have been entirely obviated by an American invention, which, with the exception of the hair-spring, makes every portion of the watch with a nicety scarcely to be surpassed. One of the chief advantages of this, it is stated, is that each part, being made by a separate machine, can, in the event of damage, be supplied through the post to any part of the world.

THE ELECTRIC TELEGRAPH.—IV.

By J. M. Wigner, B.A.

INTERRUPTIONS IN COMMUNICATION—MODE OF TESTING FOR AND LOCALISING FAULTS.

As we have already seen, any electric circuit is liable to various interruptions, which often cause serious inconvenience. It is therefore a very important matter to be able to discover the cause of the interruption, and, if it be an injury to the line, to find the exact place at which it exists, so that it may be repaired as promptly as possible. When any circuit is interrupted, the first question is to ascertain whether the fault exists in the battery, the instruments, the office, or the line.

Suppose the clerk at any office presses the key of his instrument with a view of sending a message, but finds that his own needle is not affected at all, he at once knows that something is wrong. If his own battery or instruments are out of order, and will not act, that will fully account for the failure. His first duty, therefore, is to make sure that the fault is not in his own office. For this purpose the wire where it leaves the office should be temporarily connected with the earth-plate, so as to cut the line-wire and receiving station altogether out of the circuit, and a current should then be sent again. If now the instrument acts satisfactorily, the fault is either on the line or at the receiving station, and the reason why the current would not pass is that the circuit is interrupted at one of those places.

If, however, when earth is thus put on, the needle still declines to move, the fault is evidently in the office, and may be a faulty connection, or a failure of the instruments or batteries. The latter should first be tested by connecting their two poles with a galvanometer, and noting the deflection. Should this indicate that the battery is enfeebled or impaired, it should be replaced, or set in order. It not unfrequently happens that a single cell in the trough is working badly, and has entirely stopped the passage of the current generated by the rest. In this case the defective cell must be replaced, or else bridged over by making a good connection between the cells on either side of it.

If, however, the battery is in good order, the fault must be in the instruments or their connections, and its exact place may be discovered by affixing one end of a good wire to the terminal where the line-wire leaves the instrument, and having pressed down the key so as to send a constant current, bring the other end of the wire successively in contact with the different binding-screws or connections. As soon as the fault is passed, the needle will immediately be deflected, and thus the place of the interruption will be seen.

Sometimes the injury will be found to be a rusted or dirty connection; or sometimes, if inferior oil has been used in any part of the apparatus, the dust may have settled on it, and become hardened, so that in this way a faulty contact is produced. Too much care cannot be taken in ensuring the perfect cleanliness of all connections, as, even if the current passes at first, the surface, after the lapse of a little time, becomes more corroded, and a great amount of inconvenience and loss of time may be caused in discovering the exact place. A little of the best salad oil should be applied to the pivots and points by which a contact is made, as a safer connection is ensured thereby, and this oil will not harden sufficiently to injure the contact. The contact-plate should, however, be frequently wiped to remove the dust which may have settled on it. In this way any faults in the office are easily discovered, and for the most part they may without much difficulty be rectified, unless, indeed, the needle has become demagnetised, or there is some injury to the instrument rendering necessary its return into the maker's hands. More commonly, however, the fault exists along the line. An insulator may be broken, or the wires may be so slack as to come into contact with one another, or with some obstruction which carries away a part of the current.

As considerable inconvenience and delay are caused by such faults on important lines, it is usual to test them every day with a view of discovering any flaw before it is sufficiently developed to interrupt the communications. In these tests two things are ascertained—the degree of insulation, and also the amount of resistance which is offered to the passage of the current, as sometimes the wire may be well insulated, but a defective place in it may offer such a resistance as totally to intercept a weak current. In all testing experiments the battery power employed should be as small as possible, since a powerful current will often pass a bad connection, which would quite intercept a feebler one.

A well-made galvanometer is the most important thing in testing a line. There are two different forms of this instrument in common use. In the more sensitive of these the needle is placed horizontally, being poised on a fine steel point. Friction is thus reduced to a minimum, and the only force to be overcome by the current is the directive influence of the earth's magnetism. The instrument is so placed that the needle may point to 0 on the graduated scale; the current is then applied, and the amount of deflection when the needle comes to rest is noted. This instrument is represented in Fig. 14.

In the other form of galvanometer, usually called the "detector," the needle hangs vertically inside the coils, a pointer being fixed on the same axis so as to indicate the position of the inner needle. In the more perfect instruments of this class, this outer needle is magnetised as well as the inner one, and is so mounted that its north pole shall point in the reverse direction to that of the inner one, and thus both are affected by the current round the coils, and the instrument is rendered much more sensitive. The lower end of the needle is slightly weighted, so that it hangs vertical when no current is passing. Hence this form of galvanometer is more used than the other, as it requires no adjustment of position. The graduated scale is placed above the needle, as seen in Fig. 15.

Without care the readings of a galvanometer may be misunderstood, for a deflection of 40° must not be taken as an indication that the current is just twice as strong as one producing a deflection of half that amount, or 20°. A special scale has accordingly to be provided for each instrument. In a well-made detector, the values of the degrees up to 30° were found very nearly to correspond with the strength of the current; above that the following results were obtained:—

40° deflection	represented a strength	equivalent to	44°
50°	,,	,,	65°
60°	,,	,,	93°
65°	,,	,,	150°

In another galvanometer, the values of the reading would probably differ to a considerable extent; it is necessary, therefore, for each to be graduated by actual trial.

The following is the simplest manner in which the daily tests for insulation and resistance are made:—Let A and B be the stations at the ends of the line. A puts a detector in his circuit, and then sends a current through it along the line, having first informed B, who for a short time, say two minutes, disconnects his line-wire altogether, so as to leave it completely insulated. The deflection of the detector during this period shows the amount of loss by imperfect insulation, and if this amount is above the daily average, it plainly shows some defect, as, for instance, a broken insulator. B then, for a similar period, connects his end of the line-wire to a good earth, through his own detector, and the results now obtained show the resistance to the current. A very weak battery should be employed for this purpose, since otherwise "full deflection" would almost certainly be obtained, even although a considerable fault existed. Only very rough tests can therefore be made in this way, and at all principal stations the resistances are accurately ascertained

by means of a resistance coil and a differential galvanometer. The last-named instrument consists of a magnetised needle mounted with two independent coils, each of which exerts the same influence on the needle. If, then, the current be made to pass round these in opposite directions, the needle will remain at rest, one coil exactly neutralising the effect of the other. In order to use this galvanometer, two passages are provided for the current from the battery; the resistance to be measured is made a part of one of these circuits, while in the

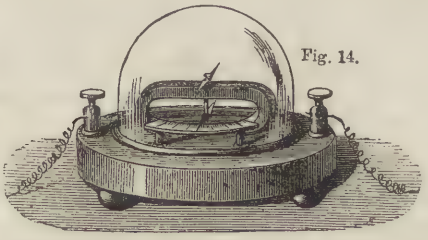


Fig. 14.

other is placed a series of resistance coils by which a known resistance can be introduced till it exactly balances the other, as shown by the needle remaining at zero.

The annexed diagram (Fig. 16) will render this more clear. B is the battery, from each pole of which there are two conducting wires. The one leads to the binding-screw A, whence the current passes round one coil to E, thence along the line-wire L, whose resistance is to be ascertained, returning either by the earth or by another wire whose resistance is known, or else similar to that being tested. The other battery wire leads to C, and from this the current passes round the other coil of the galvanometer to D, thence through the set of resistance coils R, and back to the other pole. Two courses are therefore open for the current, and it accordingly splits between them; the greater portion, however, passes along the route which offers the least resistance, and the needle is accordingly deflected by that. By means, however, of the various coils in R, the resistance in that circuit can be so adjusted as exactly to balance that of the line, which is thus ascertained. If the current returns from L by a wire similar to itself, the resistance must be divided by 2 to give that of each wire. If it returns by a wire of known resistance, that must be deducted to give the resistance of L. S is a "shunt" affixed to one of the coils of the galvanometer, so as to reduce the effect of the current upon it by providing a short path for the greater portion of the current. A peg is inserted between the pieces of brass, and offers $\frac{1}{10}$ or $\frac{1}{100}$ the resistance of the coil, round which accordingly only $\frac{1}{10}$ or $\frac{1}{100}$ of the current passes. The advantage of this is that by it a much smaller resistance coil is required, since one of 1,000 units may balance a resistance of 10,000 or

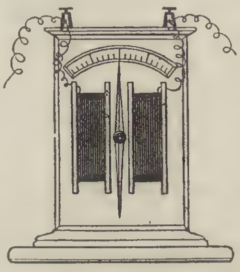


Fig. 15.

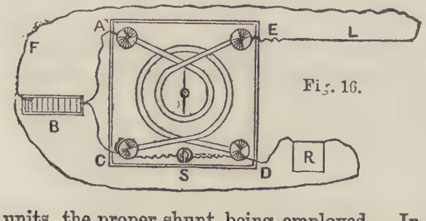


Fig. 16.

100,000 units, the proper shunt being employed. In this case the indicated resistances must of course be multiplied by 10 or 100.

When the test for insulation is being made, the further end of the line is disconnected, and the corresponding pole of the battery put to earth, as seen in Fig. 17. This circuit then can only be completed by the escape of a portion of the current from the line-wires to the ground, owing to imperfect insulation. In keeping a record of these tests, it is important to note also the state of the weather at the time of taking them, since this makes a material difference in the state of the lines.

We must now endeavour to explain roughly the manner of ascertaining the position of a fault in any line, when it has been ascertained that there is one. We must, however, first know the different kind of faults that are met with. The first is a total interruption of the circuit arising from a broken wire or some similar cause, in which case no current whatever passes. There may also be a partial want of continuity indicated by the signals at the receiving station being less distinct than usual; so much so at times as to be unintelligible.

Another defect is "earth" on the line—that is, a connection

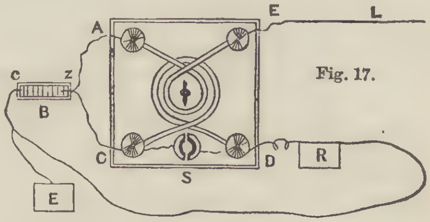


Fig. 17.

at some place between the line-wire and the ground, so that a greater or less portion of the current escapes. If the connection be a very good one, so that the whole of the current escapes, we have what is technically known as "dead earth." In this case the signals at the sending station are stronger than usual, since there is a shorter path for the current to travel along, but no signal whatever is received at the receiving station. When this happens, each station along the line should in succession transmit a current, and the interruption will evidently be beyond the last one from which a current is received. When it has been ascertained between which stations the fault lies, its place can be found by noting the resistance of that piece of line as compared with its usual resistance. If it be only half as great as usual, the fault is probably about mid-way along it, and so in proportion.

Partial earth occurs when there is a fault by which only a portion of the current escapes, and this is a more difficult fault to test for. The signals at the sending station are still unusually strong, since two return paths are open for the current, one by the fault, the other in the usual way. The signals at the receiving station are, however, weakened considerably.

The best plan of testing for a fault of this description will be understood by reference to Fig. 18, in which the battery, etc., are denoted by the same letters as before. If possible, a good wire, H, leading from the receiving station, should be used as a return wire, being connected to the faulty one at G. Let F be the place of the fault, and let the connections be made as shown. The current leaving C to the earth-plate will divide at F, a portion passing along by G, H, E, A, to Z; the other portion passes through the resistance coils R, and so to Z. If R were

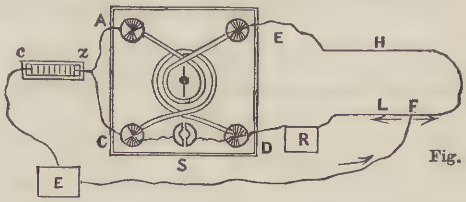


Fig. 18.

removed, the latter portion would clearly be the stronger, since it has the shorter distance to travel; by introducing a resistance, therefore, we can ascertain how much one exceeds the other, and from that we can calculate approximately the place of F. When this is done, there will probably be little difficulty in the line inspector ascertaining and repairing the damage.

If any portion of covered wire or instruments exist in the circuit either way, allowance must be made for the extra resistance caused thereby, or else the calculation will mislead. In any testing experiments the copper pole should always be put to earth, since a negative current discovers a flaw much more readily than a positive current.

OPTICAL INSTRUMENTS.—III.

BY SAMUEL HIGHLEY, F.G.S., ETC.

DIAGNOSIS FOR SPECTACLES.

To ascertain what form of lens is needed to correct the defective vision of a patient, the optician or oculist must first determine the true nature of the defect—whether it be presbyopic, myopic, or hypermetropic; and if the person is not advanced in years, great care should be taken to ascertain whether or not the last defect exists, for by a faulty diagnosis great injury might be brought about through supplying unsuitable glasses. Again, it must be determined whether failing sight is due to optical defects of vision, or to those weaknesses of sight known as amblyopia and asthenopia, which are due to irritation of parts of the eye.

First, he must determine the patient's "acuteness of vision," as it is technically termed, by exercising the eye on Dr. Snellen's "Test Types." These consist of carefully-drawn, square, lithographed letters, whose limbs have a width equal to one-fifth of the letter's height, such being generally distinctly visible to a normal eye at an angle of 5′. These letters are arranged singly or in groups, and of increasing size, with a number attached to each, to indicate the number of feet at which the particular-sized letters must be placed from a normal eye, to subtend an angle of 5′ for their height; and, further, an angle of 1′ for the breadth of the thick strokes, for determining "the minimum angular magnitude of distinct vision" (which is taken at 1′).

These types range in size from the smallest letters, to be seen at 1 foot, to 3⅞ inches in height, to be employed at 200 feet. Two diagrams are specially designed for testing the acuteness of vision at an infinite distance, that is, from 20 feet to 200 feet—one having black letters on a white ground; the other, similar letters, but white on a black ground. To normal eyes these seem nearly alike as to distinctness; but should the white letters on a black ground appear more distinct to the patient, a diminution of acuteness of vision is indicated, which probably results from diffuse light, arising from turbidity of the refractive media of the eyes. The distance from which the test-types can be distinctly recognised should be measured from the surface of the paper to the temple of the person under examination. These letters are grouped in irregular order, so that no help may be given to their recognition by juxtaposition with other letters, as would be the case were words employed; while, on the other hand, to attain, if possible, more uniform distinctness, certain letters that might lead to confusion with similar ones are omitted. Thus every care is taken to ensure a perfect and independent recognition of these letters without any extraneous help.* The degree of acuteness of vision (V) is expressed by the relation of the distance at which the letter is actually seen (d) to that at which the letter is apparent at an angle of 5′ (D).

$$V = \frac{d}{D}.$$

If No. I. is distinctly seen at a distance of one foot, and No. XX. at twenty feet, then d and D are equal, and accordingly it follows that

$$V = \frac{1}{I} = \frac{20}{XX} = 1;$$

or, in other words, there is normal acuteness of vision.

If, on the other hand, No. I. is only distinct at six inches from the eye, and No. XX. at ten feet, then d is less than D, and

$$V = \frac{\frac{1}{2}}{I} = \frac{10}{20} = \frac{1}{2}.$$

If No. XV. can only be recognised at a distance of five feet, then we get the following equation:—

$$V = \frac{5}{XV} = \frac{1}{3}.$$

If d should be greater than D, and No. XX. be thus visible at a greater distance than twenty feet, then the acuteness of vision is more than the normal average.

* An English edition of Snellen's "Test Types" is published for the benefit of the Netherlands Ophthalmic Hospital, by Messrs. Williams and Norgate.

An investigation of 281 cases of emmetropic eyes at different ages gives the following results:—

At from ten to twenty years . . . . . $V = \frac{22\frac{1}{2}}{20}$.

At thirty years . . . . $V = \frac{22}{20}$.

At fifty years . . . . $V = \frac{18}{20}$.

At sixty years . . . . $V = \frac{14}{20}$.

At eighty years . . . . $V = \frac{11}{20}$.

So, it will be observed, the normal acuteness of vision decreases with age.

Besides these tests by jumbled groups of letters, the person may be tested by reading in different-sized type, but such experiments must not be identified with the recognition of isolated letters, for the reason previously stated; but in other respects reading is a more difficult test, because the letters of words, as ordinarily printed, are very close together, hence more confusing for immediate recognition.

For testing by reading, fluency is chiefly to be regarded, for with a contracted or interrupted visual field reading is less fluent. It is obvious that this test can only be tried on persons of fair education.

Snellen's *reading tests* are printed in type as nearly as possible uniform with his *letter tests*, and the following numbers of his types correspond in height with the less scientific system of "test-types" of Professor Jäger, which, however, have been principally used in this country.*

No. I.	of Snellen's =	No. 1	of Jäger's	Test-Types.
II.	"	5	"	"
III.	"	7	"	"
IV.	"	11	"	"
V.	"	13	"	"
VII.	"	14	"	"
XVIII.	"	18	"	"
XXVII.	"	19	"	"
XXXVIII.	"	20	"	"

A good series of *reading test* may be formed of short paragraphs set up in the following well-known printer's types:—No. 1, "brilliant;" No. 2, "pearl;" No. 4, "minion;" No. 6, "bourgeois;" No. 8, "small pica;" No. 10, "pica;" No. 12, "great primer;" No. 14, "double pica;" No. 16, "two-line great primer;" No. 18, "canon;" No. 19, "four-line condensed;" No. 20, "eight-line Roman." An eye with normal acuteness of vision ought to be able to read Nos. 18, 19, and 20 of these types at a distance of twenty feet; but a person may be so amblyopic as not to be able to read the largest of Snellen at any distance. In such cases we may try whether the person is able to count fingers at different distances, or whether he can distinguish light from darkness by placing him at six feet from an argand gas-flame in a dark room, then turning the light up and down slowly; or, if this fails, from light to sudden darkness, and back again. If the patient cannot distinguish between such extremes, he must be "stone blind."

We must next test for the "range of accommodation" the patient's eyes possess, by first determining the "near-point" and then the "far-point," which may be expressed by the following formula:—

$$\frac{1}{A} = \frac{1}{p} - \frac{1}{r},$$

in which p represents the (*proximate*) nearest point of distinct vision, and r (*remote*) the farthest point of distinct vision, and $1 \div A$ the range of accommodation. For this purpose we employ an optometer, which consists of a carrier for a test-plate, and an adjustable scale that will give the exact distance between the face of the plate and the cornea of the patient's eye. The test-plate may consist of a paragraph set up in "Brilliant" or "Pearl" type, which corresponds to Nos. 1 and 2 of Jäger's reading tests; or of a little frame, 7-8ths wide in the opening, divided vertically into six parts by five fine black wires or horsehairs; or of a black

* Copies of Jäger's test-types may be obtained of the Secretary at the Royal Ophthalmic Hospital, Moorfields.

plate, pierced with little holes from 1-20th to 1-6th of a line in diameter, behind which a background of ground-glass is placed: these rapidly emit rays, and lose their round form, if not perfectly focussed on the retina. The adjustable scale may be a winder measuring tape, the ring of which is looped on to the handle that supports the test-plate; or it may be a shoemaker's rule, the fixed end of which is cut down and notched to receive the patient's eye, the test-plate being fixed to the sliding upright; or it may be a specially-designed piece of apparatus, consisting of a graduated brass rod, mounted on a firm telescopic foot by a shifting-hinged joint, on which a frame that carries the test-plate works freely up or down, and can be clamped at any desired position by means of a milled-headed screw. Whatever the arrangement, the test-plate should, as Donders has pointed out, be moved steadily up to, or away from, the eye under examination, for "ordinary individuals accommodate for their farthest point only, when they actually look at a distant object, and for their nearest only, when they very distinctly see an object approaching, whose diminishing distance they meanwhile observe and follow in their imagination. Then, by the effort actually to see the object distinctly as long as possible, the greatest power of accommodation is excited."

On sliding along the reading-test towards the eye, we soon find the nearest point at which the text can be read off. With the wire-test, the wires only appear sharply defined when the eye accommodates itself perfectly to them; directly there is a deviation in this (the frame being too near or too far from the eye), the wires seem indistinct, thicken, or as if surrounded with a halo; or even double-coloured images of them appear in the transparent intervals, as a white wall or the sky should in this test be used as a background. The same may be remarked in regard to the test-holes, for they rapidly lose their round form and emit rays when the eye is not in perfect accommodation with them. It will be readily seen that much depends upon the intelligence of the person under examination in appreciating the distinctness of the wires or the sharp form of the holes; therefore the reading-test is, as a rule, the most readily applied; for it is oftentimes absurd to what a distance persons will maintain that the wires and holes seem well defined; while, by moving the reading-test alternately nearer to and further from the eyes, we can readily ascertain with exactitude both the near and the far point of distinct vision.

If to this optometer we add an arm fitted with a six-inch convex lens, the far-point may be ascertained in all cases. If for an eye (with suspended accommodation) we have to move the test-plate to six inches' distance to secure distinct recognition, it is emmetropic; if nearer to the eye than six inches, it is myopic; if further off, it is hypermetropic. The systematic employment, in the optometer of Von Groefe, of a convex lens of only six inches focus, presents advantages over those of longer foci, as it brings the normal eye to a condition that is very nearly myopic, and so in a state more favourable for comparison. By employing an optometer of the kind last described, the far (r') and the near (p'), *thus found*, stand in such a relation to the patient's real far (r) and near (p) point, that the rays coming from r' are refracted by the lens as if they proceeded from r, and those from p' as if they emanated from p.

In the normal eye (with 6-inch convex) r' would lie at six inches from the eye, for rays from an object at six inches' distance falling on the lens would be rendered parallel by it, and would consequently impinge upon the eye as if they came from an infinite distance or the normal far-point. The near-point (p') would lie at *about* three inches, for this varies according to age.

If (with 6-inch convex) we find the far-point (r') lies at six inches, and the near-point (p') at three inches,

$$A = \frac{1}{3} - \frac{1}{6}$$

the eye is then emmetropic.

If (with 6-inch convex) we find that $r' = 5$ inches, and $p' = 3$,

$$A = \frac{1}{3} - \frac{1}{5}$$

the eye is then myopic, for it is not adjusted for the normal far-point (six inches), but for a nearer one, the rays from which impinge in a divergent direction upon the eye.

If (with 6-inch convex) we find that $r' = 8$ inches, and $p' = 3$ inches,

$$A \ \frac{1}{3} - \frac{1}{8}$$

the eye is then hypermetropic, for its far-point lies beyond the normal far-point, namely, six inches. It has been stated above that these determinations may be made *for an eye with suspended accommodation.* Now in practice this is rarely met with, except in cases where the power of accommodation is paralysed ("*paralysis of accommodation*," as it is technically termed); but we have the power of producing such a state of rest artificially, by the application of a solution of atropine (gr. iv. to ℥j) two hours prior to making the trial. As the effects of atropine last for some days, I need hardly say that the ordinary optician would not be justified in using this agent on his customers, and that its employment must be confined to the practice of the medical oculist. Moreover, as decided cases of presbyopia and myopia are readily determined by optical tests, it is only in cases of suspected hypermetropia, or for determining the whole amount of a patient's hypermetropia, that atropine is needed.

But when there is reason, from the form of the eye (see p. 160), together with complaint on the part of the patient of constant fatigue in the organs of vision, to suspect the existence of hypermetropia, the optician may make the following trial. Try the patient's eye on No. XX. of Snellen's test-types, at twenty feet distance, or on a paragraph set up in type of this size

Canon

If the eye is emmetropic, it will read this at the distance specified; and a hypermetropic eye will most probably do the same, *unless* the hypermetropia be very great, or *its accommodation has been paralysed by atropine!* Now try the patient with spectacles glazed with 20-inch lenses on the same object at the same distance; if the eye is emmetropic, it will no longer be able to read the test; while if it be hypermetropic, it will read it with greater facility than before.

In extreme hypermetropia the eyes may not be able to read the test with 20-inch lenses, but can without them. Thus assimilating to the characteristics of a normal eye makes its diagnosis by optical tests extremely difficult; but a suspicion of its existence should be created when fatigue in the eye is constantly complained of; and as the question must then be settled by ophthalmoscopic indications, it becomes the duty of the optician to direct the patient to consult an ophthalmic surgeon; for the diagnosis and mode of treatment must be medical as well as optical.

In testing for the range of accommodation, it is necessary to try both eyes of the patient; for it will often be found that the two eyes of the same individual may possess a difference in accommodative power. In other cases we may find that the near-point may be normal, but the far-point approaches nearer than an infinite distance to the eye, which might be mistaken for an indication of myopia; or the far-point may be normal, and the near-point abnormally distant from the eye; or both near and far point may have changed their normal position, and have become approximated to each other.

We may also meet with a dislocation of accommodation, without any diminution in its range.

In making trials for the far and near point, we bear in mind that in the normal eye its far-point lies at an infinite distance (symbolised by ∞), so that parallel rays are united on the retina when it is adjusted for its far-point, while its near-point lies at from four to five inches from the eye, though even a near-point of seven inches is not to be regarded as sufficiently abnormal to amount to a defective state of vision.

In testing for the near-point we may find that one person will clearly distinguish the test-plate as close as three inches, while another cannot do so nearer than thirty inches. This indicates that the one has the power of increasing the convexity of his crystalline lens by a quantity equivalent to a 3-inch glass lens; while the second can only do so to an extent equivalent to a 30-inch glass lens; and we say that the accommodation of the first equals 1-3rd, and that of the second equals 1-30th.

TECHNICAL DRAWING.—XVII.

DRAWING FOR MACHINISTS AND ENGINEERS.

FREE-HAND DRAWING.

THE great importance of Free-hand Drawing to artisans has already been insisted upon, and a few examples in this branch of the subject will be given in this part of our lessons in "Technical Drawing," in order to show the kind of practice which is deemed advisable for machinists and engineers.

Our workmen have laboured under the mistaken idea, that so long as they could manage to measure and rule the lines from a copy with some degree of neatness, they were learning Mechanical Drawing. Nor were the teachers of the period immediately preceding the present competent to give them better instruction; for whilst qualified mechanical draughtsmen were not teachers, the teachers were artists, but not engineers. It was only when the Government Department of Science and Art undertook the systematic training of masters of Schools of Art—in which not only ornamentists and designers, but artisans generally were to be taught—that this branch of the subject began to receive proper attention, and was made a portion of the certificate examination; and not only is Linear Drawing by means of instruments taught, but the artisan is shown how to sketch from objects and to draw curves by hand; in fact, an enlarged view of the whole subject has been given, of which the fruits are daily becoming more obvious. The early training of foreign artisans has in this respect been superior to ours; and in the different exhibitions which have been held in this country and on the Continent, workmen were to be seen with their note-books busily employed in collecting information, and sketching the appliances connected with their peculiar walks of industry. Such notes and sketches, however roughly done, must be a source, not only of great usefulness, but pleasure to them.

Drawing, too, constitutes a universal language, which to artisans is a matter of the utmost importance; for by its means they can illustrate the form of an object in an infinitely less period of time than by words, to persons who may not be able perfectly to understand the language of the country; in fact, in the words of Sir Joshua Reynolds, "the pencil speaks the tongue of every land."

The machinist must remember, too, that in making drawings from actual measurement, the instruments are not in the first instance employed. All the implements used are the pencil and the "two-foot rule." The draughtsman makes a rough sketch entirely by the hand and eye, measures the various parts, and jots down the measurements in his sketch. After this he reduces the whole to the required scale, and proceeds to make his mechanical drawing.

As the lessons proceed, the student will be taught how to draw from objects seen perspectively. In commencing, however, the practice is confined to a few well-known objects placed so as to present only one surface to the eye of the spectator, and which can thus be drawn as mere elevations. In the first instance tools have been chosen, because the student is supposed to be well acquainted with their forms; thus, when he has sketched them, he will, as it were, be able to check his own work, and this may, it is hoped, lead him to try his hand on other objects; he will thus gain power and courage, and will be gradually led on to attempt (and to succeed in) higher things.

Drawing, in addition to its use as a universal language, is a means of strengthening the powers of observation, and, viewed in this light, it is a study of the greatest importance to workmen. To "*look at*" is not necessarily "to *observe*"—the latter term implies a careful examination of all the parts of an object, an accurate study of the points in which they differ from others, and their peculiar adaptation to their special purpose. In this drawing materially aids the student; for as each line of the object is followed, and compared with others, the mind is led to appreciate forms which would have escaped casual observation. The artisan will understand what is meant by this accuracy in observing special forms, if he calls to mind the differences which exist in even the same tool, when adapted for the various branches of handicraft. Take, for instance, such a simple tool as a hammer, and note the variations in form between the joiner's hammer, the fitter's hammer, the smith's hammer, the watchmaker's hammer, etc.; and it must be remembered that all the differences visible are of importance in the work in which the tools are to be used.

Fig. 184 is a sketch of a pair of compasses, such as is commonly used by machinists; it is here given, in order that the student may compare it with Fig. 25, page 68, which represents the same instrument used by the carpenter or joiner; and the difference will at once become evident. The method of drawing this object being in the main the same as that already given, is not repeated here. The student is reminded, too, that even in the same branch there are different forms of the same instrument—such as the compass with a quadrant and thumb-screw, and, for finer work, the spring-dividers; all have their peculiarities, and each will afford a subject for careful study.

Fig. 185 is a machinist's screw-driver, which will afford another study as to the differences in form when compared with the joiner's screw-driver, given in page 48. In this subject, too, the horizontal centre line A B having been drawn, the directions given in connection with the former subject are to be followed.

Fig. 186 represents a pair of callipers. Draw the perpendicular A B, and the circles at the top. Next sketch the curve from C to B, and adopt as a general rule that the curve on the left side should be drawn first when another is to be drawn to balance it; for if the right curve were sketched first, the hand would cover it when drawing the other, and thus the balancing would be rendered difficult.

When this curve, then, has been satisfactorily sketched, draw a line, D, across the widest part, and from F mark off the length F E equal to F D; the curve G B may then be drawn.

The inner lines to H and I are to be straight, and from these points the inner curves to the ends of the legs are to be drawn. It will be seen that, although the callipers are open, it is advisable to continue the curves in the first instance to B, although only wanted as far as J, K.

PRACTICAL GEOMETRY.

A fair knowledge of Practical, Plane, and Solid Geometry is of the utmost importance in mechanical drawing, in which the various constructions are applied, and it is therefore assumed that the student has worked through the majority of the figures in lessons in "Practical Geometry applied to Linear Drawing" and "Projection," which are intended as stepping-stones to the present lessons.

A few additional figures, however, bearing immediately on the subjects to be delineated, are here given, and the student will find that the application of these and other scientific methods will not only enable him to work with greater accuracy than any empirical means, but will save much time and trouble.

Figs. 187 and 188 show the liability to inaccuracy where a straight line has to be drawn to touch a circle. In Fig. 187, owing to the great radius of the circle, it is almost impossible to say which is the exact point of tangent; and in Fig. 188 it will be seen that, owing to there being no definite point at which to draw the straight line, it often occurs that it is so drawn as to cut off a portion of the circle.

Fig. 189 shows two pulleys rotating in the same direction by means of a band wrapped round both.

Now it will be clear that this band must touch the circles, without cutting off any portion of the circumferences, and must therefore be composed of true tangents.

Fig. 190 will remind the student that a true tangent is at right angles to the radius drawn from the point of tangent.

Having, therefore, set off on a straight line, A B (Fig. 189), the centres of the two circles at their correct distance apart, and having described the circles, draw diameters at right angles to A B. These will cut the circles in C D and E F, thus giving the exact points which are to be joined by the straight lines of the connecting band.

Fig. 191.—*To draw tangents to a circle from a point*, A, *lying without it.*

From A draw a line to the centre of the circle, B.

Bisect A B in C.

From C, with radius C B, describe an arc cutting the circle in D and E.

Draw A D and A E, which will be the required tangents; and it will be seen that the radii drawn from D and E are at right angles to these.

Fig. 192 shows the method of drawing tangents to two circles of different diameters.

Draw a straight line through the centres A and B of the circles, and produce it.

Draw any radius in either of the circles, as B C. In the second circle, draw a radius, A D, parallel to B C.

From C draw a line through D, meeting the line of centres in E.

The point E is therefore "a point lying without the circle," from which it is required to draw a line which shall be a tangent to both circles, therefore proceed as in the last figure—viz.

Bisect the line joining E and A in F.

From F, with radius F A, describe an arc cutting the circle A in G and H. Draw the radii A G and A H.

From B draw the radii B I and B J parallel to A G and A H.

Then straight lines drawn from E through G and H will meet the circle B in I and J, and will thus be tangents to both circles.

Fig. 193.—This figure shows a driving - band crossed, by which means the pulleys are made to rotate in opposite directions.

Join the centres of the circles by the straight line A B, and draw diameters at right angles to this line, cutting the circles in C, D and E, F.

Draw C F cutting A B in G.

Bisect A G in H.

From H, with radius H A, describe an arc cutting the circle A in I and J.

Draw the radii A I and A J.

In the circle B draw the radius B K parallel to A I, and the radius B L parallel to A J.

Draw I K and J L, which, passing through G, will be the two lines required, each being tangential to both circles.

Before proceeding to the next lesson it may be mentioned that the student should keep up the constant practice of free-hand drawing, since it is only by practice that any degree of proficiency can be obtained. Amongst other subjects which might furnish good practice for free-hand drawing, are the following: a vice, a hand-vice, a hammer, a pair of plyers, a pocket-knife with one of its blades open; and then the student is advised to try his hand on parts of machines, as a hanger, a plummer-block, a crank, a cone-pulley, etc. Many of these subjects for study are to be found in the lessons in "Technical Drawing," and these may serve as guides; but in the present stage the work is to be done by free-hand only.

Again the student is urged to sketch very lightly at first, so that he may have an opportunity of reviewing his drawing as a whole before "lining in;" he can then easily rub it out and repeat the lines. In starting any subject which, like the callipers and compasses, is equally balanced, a vertical line should always be drawn. Now, some persons have from habit acquired the power of drawing horizontal lines more easily than upright ones, and therefore turn the drawing-board in order to draw the line parallel to their chest. This is a very bad practice, and should be carefully guarded against in young people.

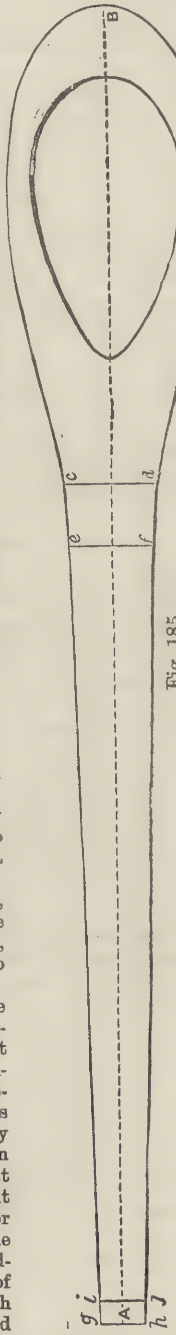


Fig. 185.

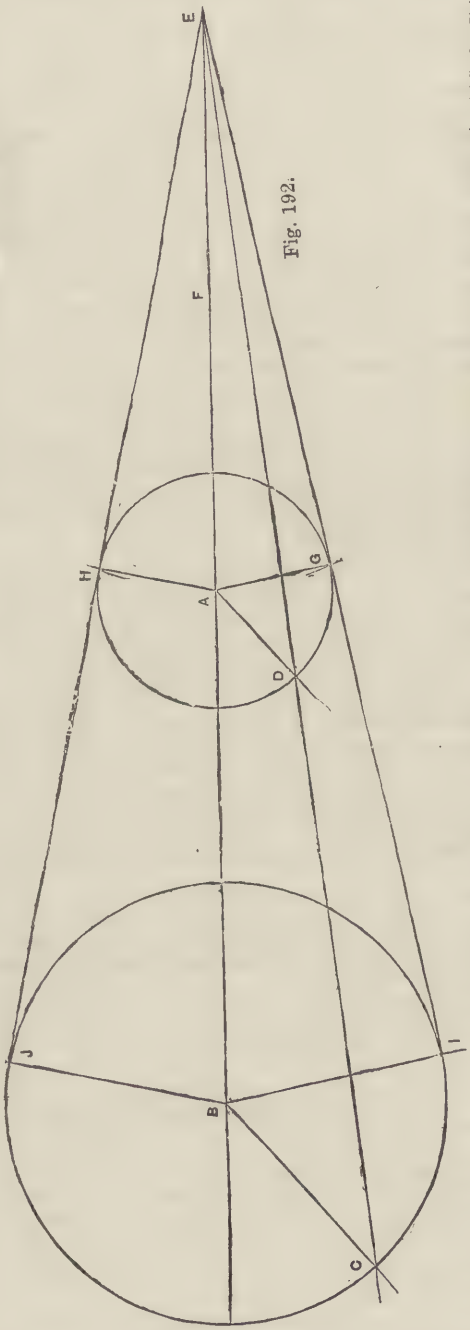


Fig. 192.

Nor should the board be turned in drawing the object itself. The left side should be drawn first, and then balanced by the right, as already described. The drawing should then be held up, and the faults in balancing will at once become visible. It is best in sketching, whether the form is to be regular or otherwise, to generalise the whole before drawing any single part definitely; by this means much time is spared, for the student will often, when he pursues the opposite plan, find he has bestowed much care on drawing one portion of the subject, which when he comes to draw the rest, he finds too large, too small, or otherwise useless. A few touches, scattered as it were over the paper, will, however, enable him to judge of the general proportions of the whole, and of the position and space which should be occupied by the details.

To do this, it is best to look upon the whole subject in the first instance as one mass, and having sketched this, find the points where it might be divided into two or three smaller portions; not absolutely drawing the lines, but marking off the spaces. By this method room will be found for all the parts, and it will be easy to get all the proportions correct.

Having thus generalised, some fixed point should next be decided upon, and this should then be sketched with some care, so that other parts dependent upon it may be properly placed. Thus proceeding, the minor details will follow in their places.

It is a good plan for artisans to repeat their drawing in ink with a steel pen, instead of using the pencil; in doing this the pen must not be pressed on, as in the down-strokes in writing, but the student must endeavour to keep a fine equal line throughout. In some cases a flat-wash of colour may be thinly and lightly spread over the representation of the object, which practice will in some degree prepare the student for the lessons to be given further on.

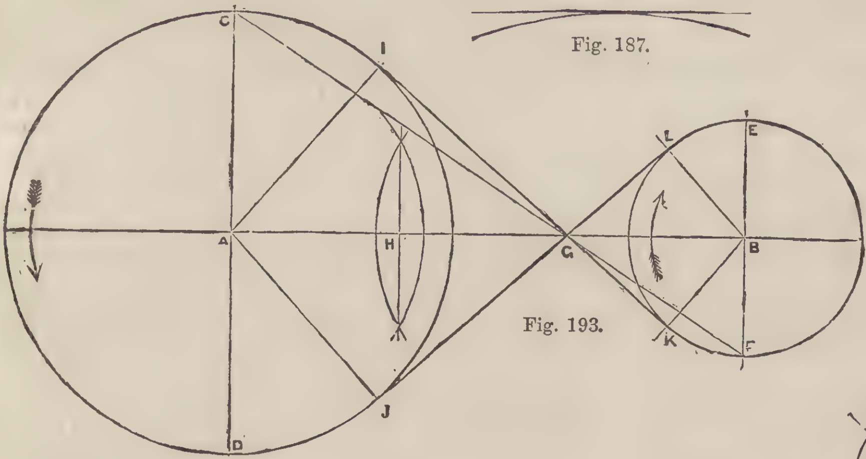


Fig. 187.

Fig. 193.

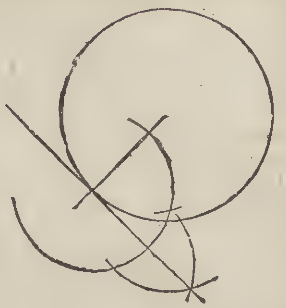


Fig. 190.

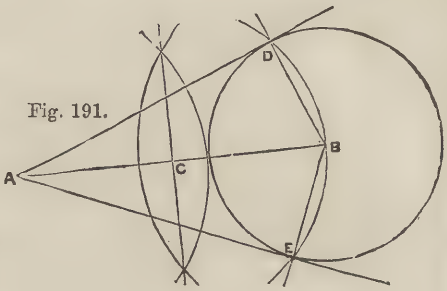


Fig. 191.

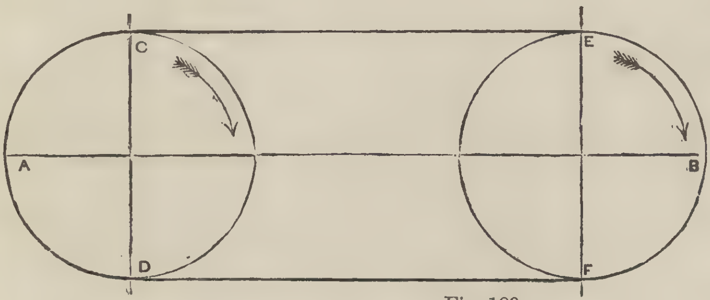


Fig. 189.

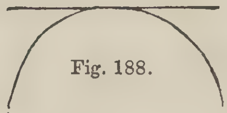


Fig. 188.

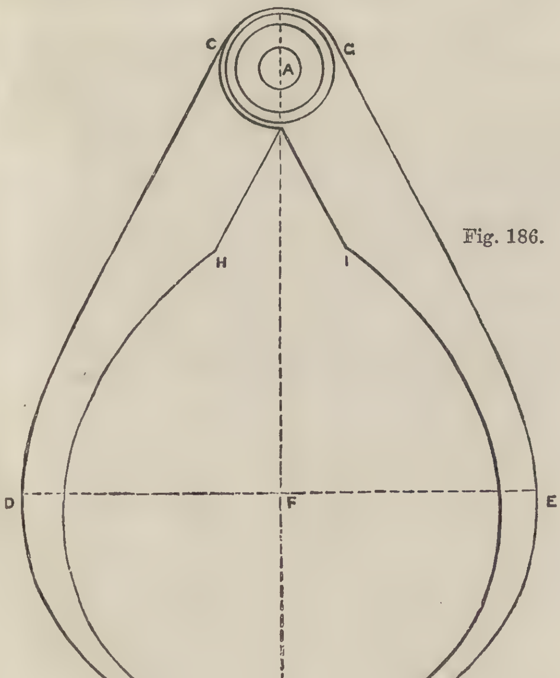


Fig. 186.

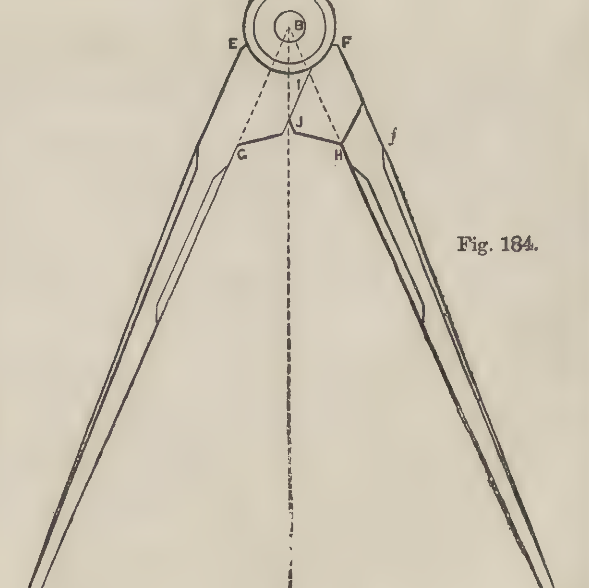


Fig. 184.

TECHNICAL EDUCATION ON THE CONTINENT.—IX.

BY ELLIS A. DAVIDSON.

THE TRADE SCHOOLS OF WURTEMBURG: STATISTICS AND WORKING.

The general system of the trade schools having been thus dwelt upon, some statistics as to the attendance and teaching staff will be interesting, as showing the extent to which the population avail themselves of the great advantages held out to them. The total number of the trade schools in Wurtemburg in 1868 was 135—viz., 102 in towns and 33 in villages, against 122 schools (97 in towns and 25 in villages) in the previous year, showing an increase of 13 in the number of schools—viz., 5 in towns and 8 in villages; united population, 490,626. The average attendance of pupils in 135 schools is 8,352, of whom 6,533 are under and 1,819 are above the age of seventeen. The number of groups into which the trade schools are classed is as follows:—

1. Trade schools holding classes on Sunday evenings as well as on the evenings of the week, and in which a drawing school is open all day; viz., Stuttgart, Ulm, Heilbron, and Reutlingen . .	4
2. Trade schools (Sunday and week-day evenings) in which there are trade but not commercial classes, but still drawing schools open all day; viz., Eszlingen, Ludwigsburg, Gmünd, Tübingen, Canstatt, Hall, Ravensburg, Biberach, Rottenburg, Kirchheim, Rottweil, Calw, Ellwangen, Ehingen, and Geislingen	15
3. Trade schools with evening classes on Sundays and week-days, but without separate drawing schools (63 towns and 22 villages)	85
4. Trade schools with classes only on the evenings of week-days (6 in towns and 2 in villages) . .	8
5. Drawing schools only (14 in towns and 9 in villages)	23
	135

It must be remarked that by the "drawing classes" are not meant the "Schools of Art," which are separate institutions, which although they give technical instruction of a high character, cannot be treated of in the circumscribed limits of these papers, and are therefore reserved for future consideration.

The number of teachers in the 135 trade schools is 489; or, on the average, 1 to each 17 pupils. The separate classes are attended by the following numbers of pupils:—

Arithmetic, 4,292; free-hand drawing, 3,951; German language, 3,819; trade drawing, 2,157; geometrical drawing, 1,969; book-keeping, 1,264; plane geometry, 1,031.

The following table shows the number of pupils and teachers in 24 of the principal schools:—

	Pupils.	Teachers.		Pupils.	Teachers.
Stuttgart . .	1117	69	Metzingen . .	100	4
Ulm	739	22	Aalen	98	6
Heilbron . .	247	12	Göppingen . .	96	7
Biberach . .	222	12	Canstatt . .	94	7
Reutlingen .	219	16	Saulgau . .	94	8
Ludwigsburg .	199	[illegible]	Hall	94	8
Ravensburg .	194	16	Nürtingen . .	89	3
Eszlingen . .	182	15	Ellwangen . .	83	3
Freudenstadt .	154	5	Rottenburg .	88	5
Geislingen . .	104	7	Rottweil . .	86	6
Heidenheim .	102	4	Tuttlingen . .	86	4
Gmünd . . .	101	5	Ehingen . .	85	4

In their annual report of the working of the trade schools, the Royal Commissioners say, that whilst testifying to the satisfactory working of the whole system, they are especially happy to see the position taken by the drawing and modelling classes, and their influence on the industries of the country.

The system on which drawing is taught is calculated to educe all the power, and to awaken the interest, of the pupils. Drawing from casts is studied at the same time as modelling from copies, the pupil thus obtaining sound notions of the relation between the "flat" and the "round." In both cases the student works to a different scale to that of the work he is reproducing, and thus his ideas of proportion are developed.

Although the greatest tact is exercised by the teachers so that the manual powers and the mental grasp of the students may not be overtaxed, and so that discouragement from failure may not ensue, still every impetus is given to progress, and every inducement to work is held out; thus, whilst idle or wilfully negligent pupils are dismissed, the utmost care is exercised, so that a pupil whose mind does not turn to any one study may be directed to another; and even if rather below the standard of the other pupils, he is placed amongst such as are willing and able to help him upward; the system of men being mutually helpful being acted upon with every success.

The work accomplished by the regular art schools (or such of the schools as possess special drawing schools) is being emulated by numerous others, and it is hoped that the results will be exhibited before long. The old-fashioned system of allowing a student to work many months at one subject requiring only manual skill—such as finely shading a drawing from a large cast with the chalk-point—is discouraged; and whilst the projection of shadows is taught on the most correct scientific principles, the mere execution is carried out boldly, and in a broad manner. Drawing from memory is much practised, and the students are taught to carry out a design, the details or natural type having been previously studied. On the whole, therefore, drawing becomes a mental rather than a merely manual exercise.

The travelling library, containing not merely books, but portfolios of engravings, which are circulated amongst the schools who apply for the loan, is a source of continual pleasure and inspiration to the pupils, who by reading of the works of the great masters, and studying illustrations of their masterpieces, see, and are led to think, that "what man has done, man can do." In old-fashioned "copy slips" used in English schools, there used to be two trite sentences which sadly puzzled boys; the one commencing the alphabet started with a capital A in the most extensive flourishes, and it said, "Attempt not impossibilities." Here, then, was the bane to all youthful aspirations; but in order to introduce the capital B the antidote came on the next page, "By attempting *im*possibilities men accomplish possibilities;" the question, however, as to what was possible or impossible, was left undecided. The copy on W was simply "Write with care." The sentiment above given, "What man has done, man can do," would have given some clue, though not a complete one; for what the great men of old did, they did by dint of labour, method, and self-culture: how much more, therefore, can our youth be expected to accomplish with opportunities such as are now at their disposal!

It is, indeed, satisfactory to know that in regard to the loans of books, pictures, etc., we are carrying out a similar system in this country, and that the most valuable and unique works are circulated from the magnificent museum and library at South Kensington to such schools of art as make arrangements to receive them, and enter into the proper guarantees for their safe keeping.

The means for public instruction in Wurtemburg are so very numerous, that it is impossible here to do more than mention the various institutions. Amongst these may be named—The University of Tübingen, in which the curriculum of education is of the widest character—literary, classical, mathematical, medical, surgical, theological, philosophical, chemical, etc.; the Agricultural School, comprising all the branches of knowledge comprehended by that term—farm management, farm buildings, gardening science, the commercial arrangements of farm land, measuring and valuing, agricultural botany, chemistry and geology, etc.; the Veterinary Schools, with their concomitant courses of instruction; the Polytechnic School of Stuttgart, of a character similar to that of Hanover, already described; the Building School at Stuttgart, of which an account will be presently given; the Schools of Art; the "Real" Schools, for higher and extended education of middle and upper classes; the Public Primary Schools; Industrial, Blind, and Deaf and Dumb Schools, etc. All show the deep sense of the responsibility which the enlightened Government feel for the welfare of the people, and of the duty they recognise as incumbent upon them to provide a full and practical education for all classes of the community; but this is not all—the great educational scheme is not a new one; it has now been going on for many, many years, each year only showing further development. It is clear, then, that the authorities would not go on adding schools and assistance if they were not demanded by the people; nor would the numerous institutions be kept up, were they not found of use or value; the plan being, as has already been set forth, to assist, but not to supersede, local effort.

The purpose, therefore, of these papers is to show to our people what is being done abroad, not merely as "a tale that is told," but to urge on them the necessity of a united effort; first, to avail themselves of such opportunities as already exist; secondly, to show by their attendance and numbers that they are willing to receive instruction, and to benefit by it; and, thirdly, to demand a further development of the germs, so that every working man in this country may be able to obtain the instruction which he finds necessary for his special branch of industry.

We will conclude our notices of the excellent technical schools of Wurtemburg with a brief account of

THE SCHOOL OF PRACTICAL BUILDING AT STUTTGART.

The object of this school is to give a thoroughly systematic education, in the scientific principles of their trades, to the following classes of persons engaged in the building trades :—

1. Skilled artisans, masons, stone-carvers, carpenters, etc.
2. Builders' clerks, including clerks of works, surveyors, etc.
3. Sluice and mill builders.
4. All trades of which geometry forms the basis.

In the general working of the school there are courses of instruction adapted for plasterers, bricklayers, tilers and slaters, millwrights, mechanics and locksmiths, carpenters, glaziers, plumbers, turners, house and room painters and decorators, ornamental carvers and modellers, engravers, silver and gold workers, gardeners, and all other trades, in fact, dependent on drawing.

The working of this school is carried on throughout the year; and the work of each half-year is divided into five courses, so that a student has the opportunity of attending all the courses in one half-year or the other, of taking some in one half-year and some in the other, or of attending both.

Further, students who, on completing the whole of the courses, wish to continue the study of architectural design and building construction, are permitted to remain for that purpose.

The students who really intend following any branch of the building trades are not only instructed in theory but practice.

There are workshops attached to the school in which manual work is taught, but only such branches are there carried on as are not practised in the locality, or are insufficiently known. Visits are constantly paid to large works in the neighbourhood.

The school is divided into five sections :—

1st Class. This class is intended for pupils who have received their previous education in a parish school, or who, although they may have attended any other schools, have not acquired sufficient knowledge to permit of their entering any higher class in the school. The subjects of instruction are German, French, history, geography, writing, arithmetic, elementary geometry, free-hand and geometrical drawing.

2nd Class. Advanced German, French and writing, geometry and stereometry, algebra, building drawing, drawing for builders, Gothic architecture, ornamental drawing.

3rd Class. Natural history and physics, descriptive geometry, trigonometry, practical geometry, architectural drawing, ornamental drawing, architecture, building construction.

4th Class. Mechanics, applied practical geometry (including stone-cutting), the projection of shadows, perspective, architectural and ornamental drawing, building materials, architecture, building construction, practical building, the implements and mechanical apparatus used, arrangements for warming and ventilating, architectural styles, the construction of roads and railways, specifications and the cost of buildings, rural architecture, practical mathematics.

5th Class. Architectural designing and construction of working drawings for building purposes, applied mathematics and physics, considerations as to sites, account keeping, etc.

There is also a separate section for the special instruction of "geometers" (*i.e.*, all other trades or professions in which geometry forms the basis), a school of hydraulic architecture, and a class for the study of machinery. Visits are paid to workshops and buildings in course of erection, and excursions are made for the purpose of practising land-surveying.

The students are classed as ordinary and extra-ordinary, the former being such as attend the entire course; while the latter are such as attend other schools, or are already engaged in trade, and who enter for certain courses only; the admission of these depends on the vacancies in the regular school.

BUILDING CONSTRUCTION.—IX.

ARCHES (*continued*).

WE now come to the square-headed window (Fig. 63), referred to in the last lesson.

Draw a perpendicular, A B, and at the point C draw a horizontal line; the point C representing the height of the top line of the sill from the ground, or some fixed horizontal line, such as a string course.

On each side of C set off half the width of the window, D and E; and at these points erect perpendiculars of indefinite height.

Now as the whole height of the jamb is to be thirty bricks, take the height of ten bricks, or any other multiple of thirty,

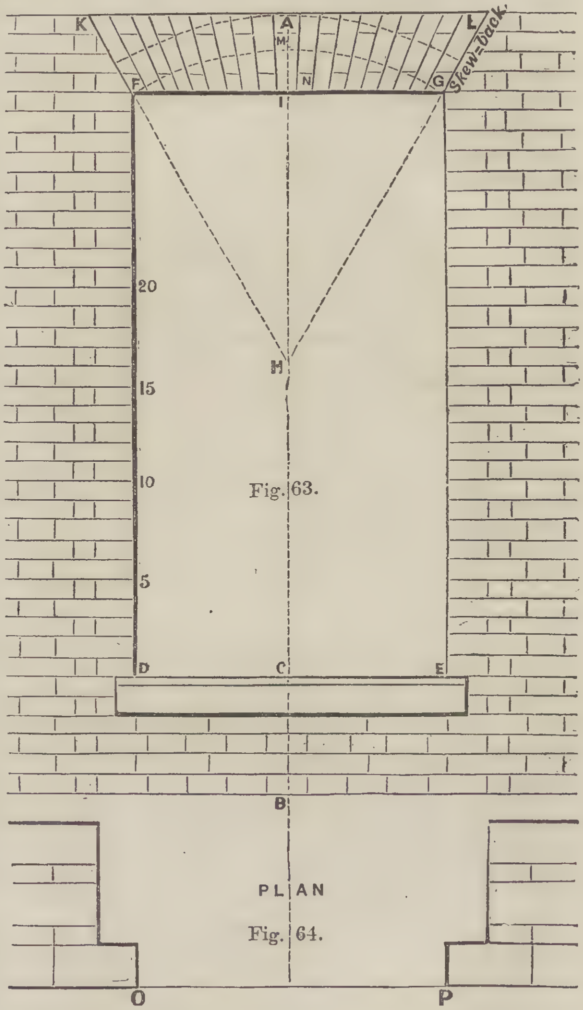


Fig. 63.

Fig. 64.

and set it off on the perpendicular D, as many times as may be required; then subdivide each of these spaces (5, 10, 15, etc.) into the proper number of bricks (this is more accurate than to set off the bricks separately); then from the highest point, draw the horizontal F G, cutting the perpendicular in I. This will complete the oblong for the window, and the line F G will form the *intrados*, or soffit, of the square arch.

Now it has already been stated that the "skew-back" usually inclines at 60°; therefore, on F G construct the equilateral triangle F G H, and produce the sides beyond F and G.

The height of a gauged arch must be some multiple of the height of one brick, on the flat with its joint—viz., three or four courses—in this instance say four; therefore, draw at that height the line K L, which will give the *extrados* of the arch.

Set off on each side of the central perpendicular on the *extrados* half the thickness of a brick, and then fill up the remaining portion of the line on each side with the widths of

bricks. From each of these points draw lines to H, which will divide the general form of the arch into a number of wedges. This will complete the straight arch. As the whole thickness of such an arch, reckoning it obliquely according to the lines of the joints of the arch bricks, and which therefore varies according to the situation of those joints, cannot be obtained from one brick, the depth is usually made up of two pieces. But the horizontal lines, M and N, are not the real joints, but false ones. marked for effect; the real joints are not horizontal, but perpendicular to the centre line of the brick. The real joint soon becomes visible when time has changed the colour of the bricks.

Having done this, through the points of division in the sides draw horizontal lines, which may be carried over to the other side; in fact, if there are several windows, or even if the courses are to be marked, they may be carried along the whole elevation, and will save all the trouble of repeating the measurement. A practical hint is, however, necessary, in order to secure accuracy in this operation. First, be very careful that your T-square is held tightly against the left edge of your board, and as you move your pencil along, let your right hand press on the blade, to prevent it rising at the middle or distant part. Where this occurs, the pencil or pen-point is liable to travel out of the required track. It is advisable to mark off with compasses on the last window, or on a line at the extreme right of the board, a few of the points, such as D 5, D 10, etc.; these will act as guide-points, and will serve to check the work. The rest of the window will be completed by marking off the whole bricks, halves, and closers, and drawing the necessary vertical lines.

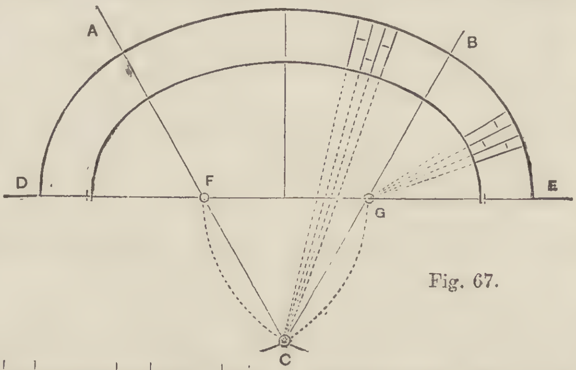


Fig. 67.

It will be seen that in this window the stone sill occupies the height of two bricks. When this has been drawn, the number of courses of bricks underneath may be added according to circumstances.

Fig. 64 shows the plan of the same window. If the elevation is to be projected from a given plan, this must be finished first; and perpendiculars raised from O and P, which will give the width of the window.

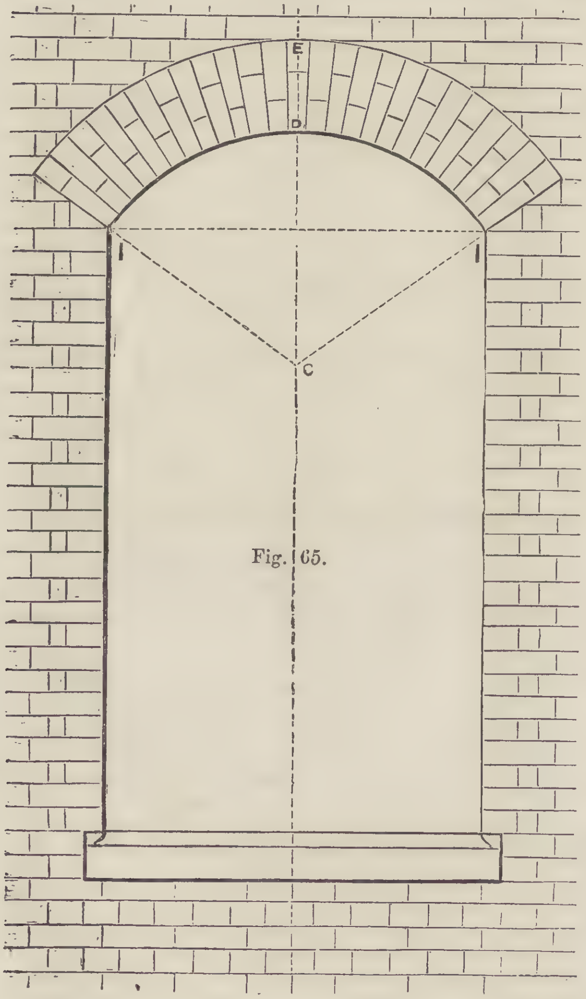


Fig. 65.

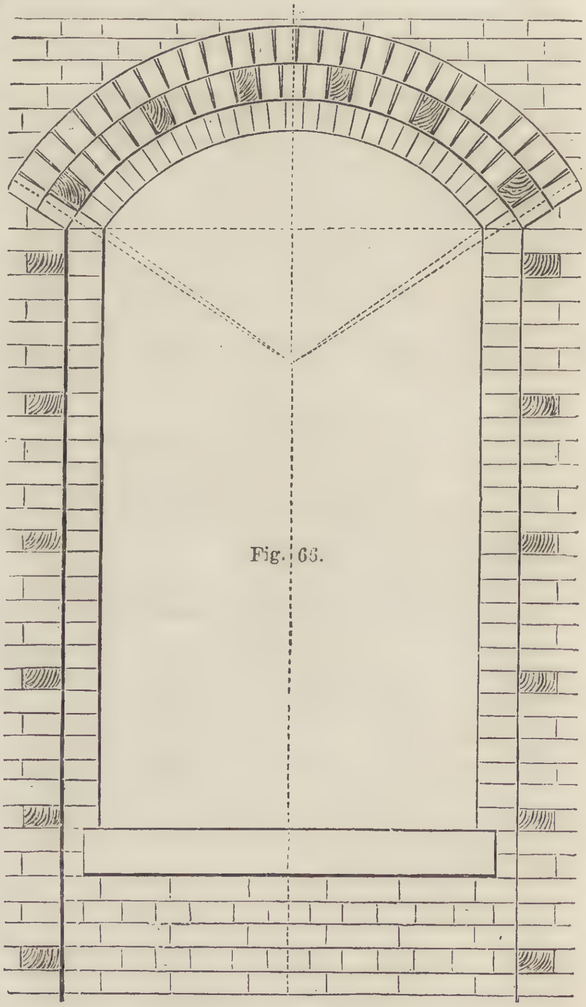


Fig. 66.

Fig. 65 is a study of the front elevation of a window, the head of which is formed by a segment arch, gauged. The general form of the aperture, and the courses of bricks, the sill, etc., will all be done by the method shown in the former subject.

The centre having been fixed at C, draw radii from it touching the imposts I, I. The position of the centre will, of course, depend on the sweep or curve which is to constitute the *intrados* of the arch; for, of course, the lower the centre be placed, the longer will be the radius, and hence the flatter the arc.

Now set off D E equal to the intended height of the arch—in this case 12 inches; with C E as radius describe the *extrados*, and on it set off the width of the bricks; that is, the length of their *shortest edges*. From these points draw radii to the centre, which will give the wedge-like divisions in the arch. Divide these alternately into brick and half-brick, and complete the rest of the brickwork and sill.

Fig. 66 is the back or interior of the same window. Here it will be seen that the arch at the back is formed of *two* rings of half-a-brick each, worked as *rough* arches; the lower portion of the width of the gauged arch is thus left, and forms the revel (or reveal). This elevation shows also the positions of the wood-bricks for the attachment of the woodwork.

Segment arches are not deemed advisable in the elevations of detached or corner houses, for although they may be safe as far as the middle arches are concerned, since the thrust of each counteracts the other, and they receive mutual support from the pier, which is common to both, yet in regard to the outer arch this is not so; and as its thrust will be obliquely outwards, there will be the tendency to force the wall out of the perpendicular.

Semi-circular and elliptical arches are not, however, open to this objection, as in these the thrust is more directly downwards.

Fig. 67 is a semi-elliptical arch, using the term in an approximate sense, for it will be remembered that, strictly speaking, no portion of an ellipse is a part of a circle. The figure, however, shows the form adopted for general purposes, and the construction of such an elliptical figure will be given in a future lesson of "Practical Geometry applied to Linear Drawing."

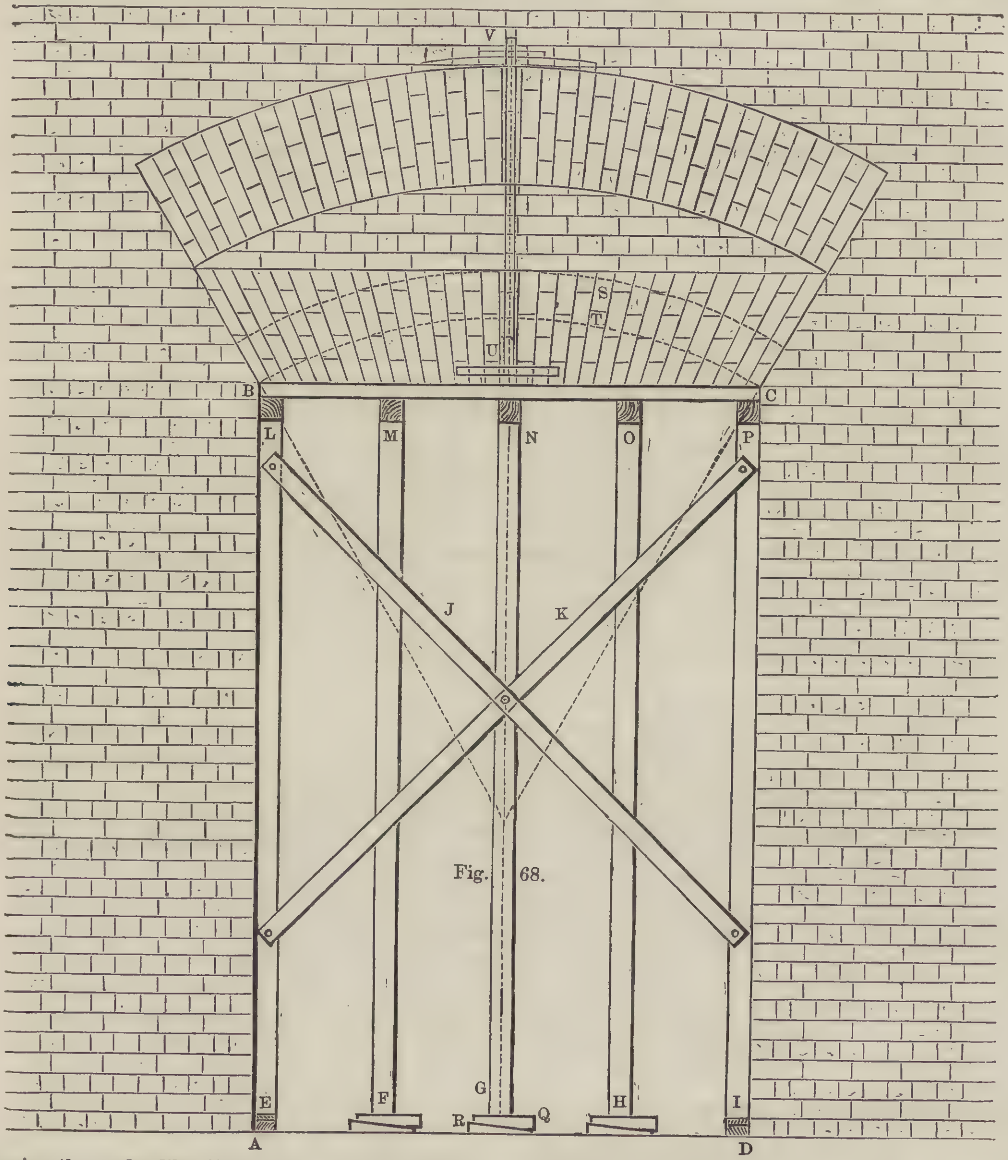


Fig. 68.

The span and rise—that is, the long and half of the short diameter—being given, construct the ellipse, and another parallel to it, struck from the same centres.

Set off on the outer curve the sizes of the bricks, and then the radii are to be drawn to the centres from which the arcs on which they are placed are struck. Thus all those between A and B will be drawn to the centre C, whilst all those between A and D and B and E will be drawn to F and G.

This subject will be further treated of when the construction of stone arches is described.

Fig. 68, taken from an excellent German example, shows the union of the straight with the segment arch.

CHEMISTRY APPLIED TO THE ARTS.—V.

BY GEORGE GLADSTONE, F.C.S.

CALICO PRINTING (*continued*).

The style of printing described in the previous lesson relates exclusively to the production of a pattern in one or more colours upon a white ground. There are, however, a variety of other effects which it is desirable to produce, that either call for a modification of the plan which has been detailed already, or for the introduction of fresh processes. These must now occupy our attention.

In many finished goods the pattern is white or tinted, while the ground is coloured. There are various ways of producing this effect. We will take first a white pattern upon blue. A resist, as it is termed, composed of acetate and sulphate of copper, thickened with gum and pipeclay, would be printed upon those portions which are to remain white, and the cloth would then be suspended in a rather moist atmosphere for a couple of days, to secure its taking thorough hold of the fabric. It may then be dyed in the indigo vat in the usual way. The portions covered by the resist are preserved from contact with the dye, and the copper salts contained in it act as a double preventive, by also withdrawing the lime from the solution of indigo which comes into contact with them, and which is necessary to its solubility, thus producing an insoluble compound on the exterior of the resist, which is subsequently easily removed by washing. Sulphate of zinc is sometimes preferred to the salts of copper; it produces the same result, by causing the oxidation of the indigo, and thus rendering it insoluble.

A yellow pattern upon a blue ground would be obtained by printing the cloth with a resist as before, and then dyeing the cloth in the indigo vat; but in this case the resist must contain nitrate of lead, as well as the copper salts and the usual thickenings; and after having been dyed the cloth must be dipped in a weak solution of bichromate of potash, when the chromium will combine with the lead in the resist, and produce the yellow colour in the pattern which is due to chromate of lead.

The vegetable colours described in the last lesson may be printed upon a cloth which is to be dyed blue by indigo; thus, a pattern in red may be produced with madder, by adopting the following procedure. The resist must contain alum and other mordants, as in dyeing Turkey red, mixed with gum and pipeclay for thickening; and the pattern be printed with it on the cloth in the usual way. After being left to age for a couple of days, the fabric has to be passed through the indigo vat, which will furnish the necessary grounding, then dunged and dyed with madder, and finally brightened with bran and soap. It will be readily seen from these instances that almost any combinations of colours may be produced in the pattern without affecting the blue grounds; just as any number of colours may be printed on a white ground, by making a proper selection of the ingredients composing the resist, the indigo having no effect upon the parts so protected, while, on the other hand, the dyes used for the pattern will not permanently fix upon any portions but those impregnated with the appropriate mordants and alterants. In dyeing the ground, however, it is not usual to immerse the goods in the indigo vat as described in Lesson II., but merely to pass them through the vat once, by carrying them over a series of rollers passing under the liquid, during the course of which they get sufficiently impregnated with the dye for this purpose.

It may be desired to produce a pattern in white, upon a ground of some other colour than indigo blue, and one that can only be fixed by a mordant. The resist will then be made of gum and pipeclay, mixed with lime-juice or other acid ingredient which shall be capable of combining with the mordant so as to produce a soluble compound. Such a resist will effectually protect those portions of the cloth printed with it from the iron and aluminous mordants used in dyeing with madder and other vegetable colours. Tinted figures may also be produced with such groundings, by including the salts of tin in the resist. In these cases the usual processes of mordanting, ageing, dunging, and clearing will have to be gone through after the reserves have been printed with the resist.

We must now consider a totally different plan of attaining the same result, and one which is adopted in many large works. Instead of preserving the pattern from the influence of the dye by means of resists, it consists in depriving portions of the cloth of the colour they possess, in order to produce a pattern. This is technically called *discharging*. It is the very opposite of the preceding operation. For this purpose the usual bleaching agents are in requisition, but they have to be differently applied, as their action has to be limited to those spots which are to constitute the pattern. The ordinary process of bleaching by chlorine is, comparatively speaking, a slow one, but it can be greatly expedited by the addition of an acid to set free the chlorine contained in the bleaching-powder. A piece of goods uniformly dyed with madder in the usual way can have a pattern printed upon it containing an acid discharger, and on immersing it afterwards in a solution of chloride of lime, the parts printed with the discharger will be bleached by the chlorine set free by the acid, before the liquor will have exercised any appreciable effect upon the portions not so printed. The operation is, of course, stopped the moment that the pattern has been properly developed, which ordinarily will not occupy more than two or three minutes, on which account it is found most convenient merely to draw the cloth through the liquid by passing it between squeezing rollers. After passing the second pair of these it goes into the dash-wheel, in order to be thoroughly washed.

Another plan of applying the bleaching liquor to certain portions of the surface is largely adopted in printing handkerchiefs in imitation of the Indian bandanas, in which the aid of powerful machinery is brought into requisition. Hydraulic presses are employed, which convey motion to two plates, an upper and an under, which are perforated with holes exactly corresponding with the spots which are to be bleached. Upon the lower plate a number of pieces of Turkey red cloth are laid very evenly, and it is then raised by the hydraulic pump until it presses against the upper plate with the force of about 300 tons. The bleaching liquor is then poured into the interstices in the upper plate which form the pattern, and passing through the cloth and out by the corresponding spaces in the lower plate, it carries with it all the colour, while the rest of the cloth is preserved from any action of the chlorine by the extreme pressure put upon it. The action of the bleaching liquor is accelerated by mixing with it some sulphuric acid, and if a strong solution is used the chlorine is forced through by artificial pressure. As soon as this process is accomplished, pure water is passed through in the same manner, in order to wash away the chlorine. If, instead of a white pattern, one of some other colour be desired, it can be communicated without removing the goods from the press; but when the whites are to be filled up with some parti-coloured device, the hand-block is generally used for the purpose.

When a discharge is to be produced upon an article dyed with indigo, chromic acid is used instead of chlorine. The plan adopted is as follows:—The surface of the blue cloth is padded with a solution of bichlorate of potash, by passing it under a roller the lower portion of which is immersed in the liquid, then between the drying rollers to squeeze out the excess, and afterwards through a hot flue; it is then printed with a discharger ordinarily made of oxalic and sulphuric acids thickened with starch, and immediately washed in water containing a little chalk. The acids contained in the discharger combine with the potash, leaving the chromic acid free to act upon the indigo, and so depriving the latter immediately of its colour. The cloth is then thoroughly washed in the dash-wheel. If some of the salts of lead be added to the discharger, a yellow instead of a white pattern will be the result.

In cases where dyes are employed which require the presence of mordants or alterants, the dischargers are used before dyeing instead of afterwards. The object then is to annul the effect of the mordant, so that at the subsequent process of dyeing the colouring matter shall not take permanent hold of those parts which are to remain white. The mordants generally used for vegetable dyes—alum and the salts of iron—are best neutralised by lime-juice, tartaric and oxalic acids, thickened in the usual manner.

Mineral colours are usually discharged in the same way as the mordants above described, and by means of the same acids, the result being that the salt of the metal enters into combination with the acid, forming a compound which in some instances is colourless, and in others can be removed by washing; in either case the desired effect is equally attained. If Prussian blue is the colouring material, the cloth must be first printed

with a paste made with caustic alkali, and then immersed in oxalic acid. The process already described in dyeing with this colour will then be reversed on these portions of the fabric, and the resulting compounds will prove removable by washing. Sometimes, however, it is the object of the dyer to combine with the discharger other substances which shall act as mordants for colours to be subsequently applied; thus the protochloride of tin may be used to decompose a brown produced by manganese, and at the same time form a mordant for such dye-stuffs as quercitron or logwood; and further combinations may be made, each several discharger being applied in succession by a different cylinder, so as to produce at the subsequent dyeing so many different shades or colours in the pattern.

There is again another process for printing a pattern in various shades of blue, which is a modification of the ordinary mode of dyeing with indigo. It is only applicable to this particular dye, but is, nevertheless, of sufficient importance to warrant a detailed description. Instead of converting the blue indigo of commerce into the white soluble indigo in the vat, and then working the whole piece in the liquid, which would produce a uniform depth of colour throughout, the indigo is printed on the material in its blue state, and is afterwards dissolved. By this means a permanent figure in blue can be produced upon a white ground, and, by varying the strength of the composition communicated to it by the cylinder or block, any required shade or any number of shades can be obtained. The composition used for this purpose usually contains about equal weights of indigo and sulphate of iron, finely ground, and mixed up into a paste with a varying quantity of gum-water or starch, according to the depth of colour required. Sometimes the acetate of iron is substituted for the sulphate. As many pastes of different strengths as may be wished are printed from successive cylinders upon the white cloth, and it is then hung up to dry for about a couple of days. Three vats are then prepared, the first containing an aqueous solution of lime, the second of sulphate of iron, and the third of caustic soda. Into these vats the cloth is dipped in the following order—into the lime and iron twice alternately, then into the soda, next into the iron and lime twice alternately, then again into the iron, and lastly into the soda. Each dipping should occupy ten minutes, with an interval between each of five minutes, to allow for the solution draining off. The oxide of iron which will be deposited on the goods during these immersions is got rid of by passing them through a bath of dilute sulphuric acid, after which they are well washed in pure water. The materials employed will be seen to be nearly the same as those used for dyeing in the indigo vat, and the result is due to the same chemical action. At each immersion in the lime-vat a certain portion of the sulphate or acetate of iron is decomposed, and an equivalent quantity of the indigo rendered soluble, which then enters into the fabric, and becomes oxidised again while the cloth is hanging up to drain, so that by the time it has undergone the series of dippings prescribed a sufficient depth of colour will have been attained. This style is generally known as "China blue printing."

Vegetable dyes used with the salts of tin, commonly called "spirit colours," produce brilliant patterns, but unfortunately they are not fast. Many colours may, however, be printed with a mordant, and then fixed by the action of steam, so as to produce an effective and permanent design. For this purpose a steam-chest has to be provided, in the upper part of which the goods are suspended for half to three-quarters of an hour, while the steam is let in by a pipe from below, care being taken not to let the steam condense upon them, or the dyes would be apt to run. In some dye-works high-pressure steam is applied, when the duration of the steaming is reduced to one-half the time. A good red is obtained by this process with Brazil or sapan-wood printed with an aluminous mordant, and a very brilliant colour with cochineal combined with chloride of tin and oxalic acid. Yellow berries are generally used for the colour indicated by their name, which may be employed either alone or with a tin mordant, the latter communicating to them an additional brilliance. The ferrocyanide of potassium is always used when a steam blue is required. Black can be produced by this means; an extract of logwood and galls combined with an iron mordant producing the reaction which has already been described in the lesson on dyeing.

The intelligent reader will not fail to observe that the various processes described in this and the preceding article are capable of being combined, and some of the best effects are realised by a combination of one or more of them. In order to avoid confusion, the printing of cotton goods has been exclusively treated; woollens and mixed fabrics have also to be dealt with in practice, but these are of so much less importance that the reader must be left to apply to them such modifications as will be suggested by a consideration of the principles which have already been laid down when speaking of the dyeing of these classes of goods.

PROJECTION.—XI.

ISOMETRICAL PROJECTION.*

In all the previous constructions, it will have been observed that the projections have been obtained by the union of *plans* and *elevations*.

Isometrical Projection enables the draughtsman to work out views of buildings, etc., without these separate drawings, but still embodying both. This most useful system may be called the perspective of the workshop, as by its means we are enabled, not only to show in one drawing a view of the complete object, but all the lines of the projection may be measured by a uniform scale; and hence the name, *isometrical*, derived from two Greek words meaning "equal measures."

In this respect it differs from perspective, in which the sizes of all objects and lines diminish as they recede into the distance, according to distinct optical laws; and it differs also from orthographic projection (which has formed the subject of our study hitherto), as in that branch of science the lengths of the lines are altered according to the angle at which the object may be placed. The whole system of isometrical projection is based on a cube resting on one of its solid angles, whilst its base is raised until the one solid diagonal—that is, the diagonal which connects the one angle of the top to the opposite angle of the bottom—is parallel to the horizontal plane. Then, if the cube be rotated on the angle on which it rests until the diagonal is at right angles to the vertical plane, the projection of the cube will be a regular hexagon. This will be clearly understood on referring to the following figures.

THE ISOMETRICAL PROJECTION OF A CUBE.

Fig. 115 is the plan and Fig. 116 is the elevation of a cube, when raised on the solid angle a, so that the solid diagonal, A b, is horizontal, and thus when rotated on a, until A B is at right angles to the vertical plane, as in Fig. 117, the point b is hidden by the point A, and the projection will be seen to be a *regular hexagon.*

Now we know that when a regular hexagon stands on one angle, so that a line drawn from that angle to the centre may be quite upright, the two sides adjacent will be at 30° to the line on which the figure stands; and this knowledge enables us to draw the isometrical projection of a cube without plan or elevation, but by means of the set-square of 30°, 60°, and 90°, by simply placing it with the long side of the right angle against the T-square (see Fig. 118), and having drawn one line of the hexagon, reversing the set-square and drawing the other, then either moving the square along until its short edge is at the point of meeting of the two previously drawn lines, or turning it so that the short edge rests on the set-square, and thus drawing the vertical line. These three lines are then to be made equal, and the upper lines of the hexagon may be drawn, by again placing the set-square in the first and second position when the T-square is moved higher up on the board. All the lines forming the projection of the cube will thus be seen to be equal, but they will *not* be the real size which they would be in the plan or elevation, but will all of them bear the same proportion to the original measurement, and may therefore be measured by a uniform scale throughout.

To understand the construction of the isometrical scale, observe that the square, A B C D (Fig. 115), is represented in the projection (Fig. 119) by the lozenge, A′ C b D, and that all the other sides, which we know to be squares equal to A B C D, are represented by lozenges similar and equal to A′ C b D. In Fig. 119, therefore, this lozenge is placed within the square, and it will then be seen that the side D B of the square is at 45° to

* Invented by Professor Farish, of Cambridge, about 1820.

Fig. 117.

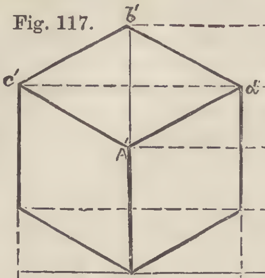


Fig. 116.

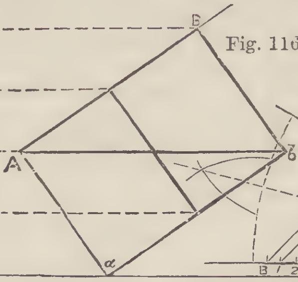


Fig. 120.

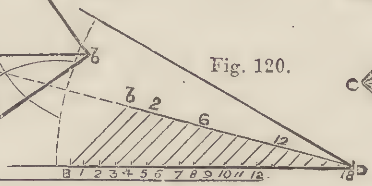
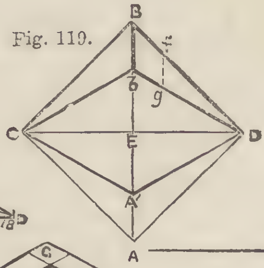


Fig. 119.



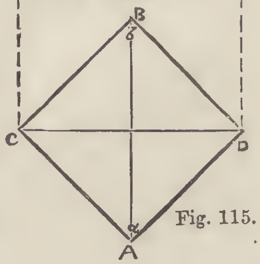


Fig. 115.

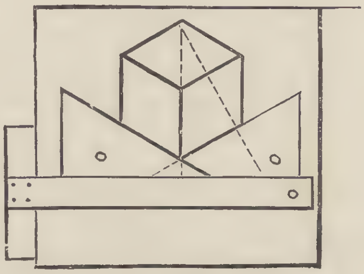


Fig. 118.

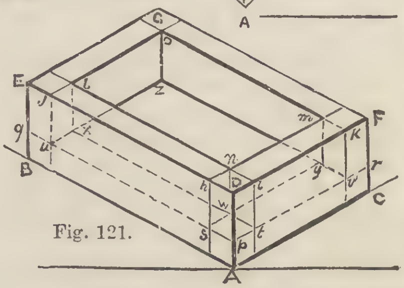


Fig. 121.

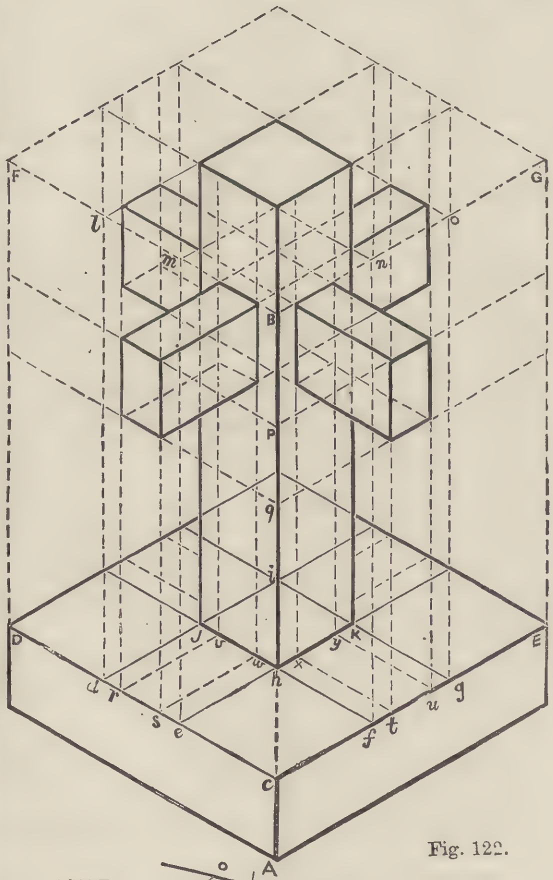
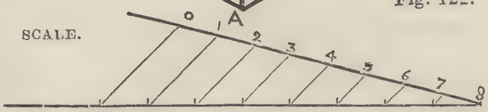


Fig. 122.

SCALE.



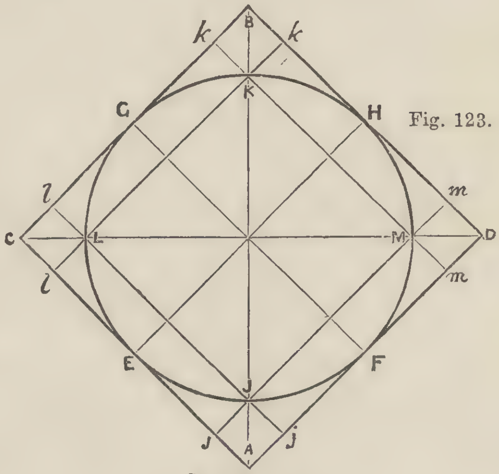


Fig. 123.

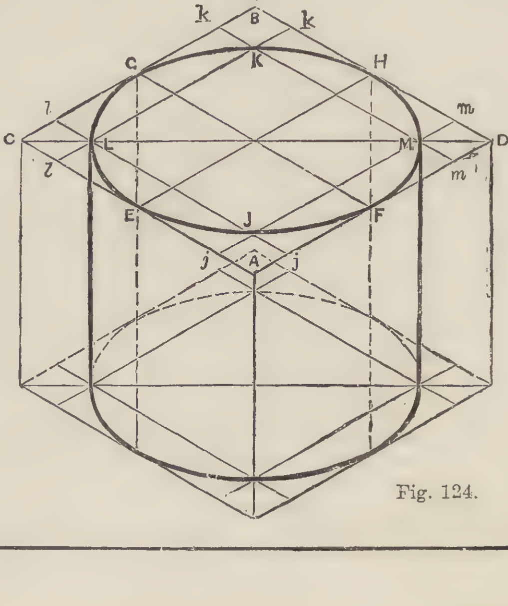


Fig. 124.

D E, whilst the side of the lozenge, D b, is at 30° to D E. The difference, then, between the triangle D E b and the triangle D E B, is the triangle D b B, the angle b D B being 15°, and D B b being 45°.

It will therefore be plain that if a side of a cube be given, and we are required to find the side of the hexagon which should form the isometric projection of the cube, we need only take the given length as the base of a triangle, as D B. Construct an angle of 15° at one end (D) and of 45° at the other (B). Then the side D b of such triangle will be the required length of the side of the hexagon, and any divisions or parts marked on B D, as B f, may be transferred to b D, by drawing a line from f, parallel to B b, cutting b D in g; then b g will have the same proportion to B D that B f has to B D.

TO CONSTRUCT AN ISOMETRICAL SCALE.

Now let it be required to construct an isometrical scale, so that the object delineated may be one-twelfth of the real size. It will, of course, be understood that this scale is *one inch* to the foot, as an inch is one-twelfth of a foot; and further, that if this inch be divided into twelve equal parts, each of the twelfths will represent the *inches* of the real measurement; that is, they will bear the same relation to an inch that an inch does to a foot—viz., one-twelfth; and, therefore, as in the proposed scale an *inch* represents a *foot*, necessarily a twelfth of an inch represents an inch. The object to be projected is a box, 1′ 6″ long, 1′ 0″ wide, and 6″ high; the sides and bottom being 2″ thick.*

Draw the line B D (Fig. 120) an inch and a half long, representing the real length of the box—viz., a *foot* and a *half*, and mark on this the twelfths of inches, which are to *represent inches* on the scale. Draw at D a line at 15° to D B (which is most accurately done by drawing a line with your 30° set-square, and bisecting the angle). Draw at B a line at 45° to B D, cutting the line drawn from D in b; then the triangle B b D in Fig. 120 will be similar to the triangle D b B in Fig. 119, and therefore D b in Fig. 120 will have the same proportion to B D that the lines similarly lettered in Fig. 119 have to each other. From the points 1, 2, 3, 4, etc., in B D draw lines parallel to B b, and these will divide b D proportionately to B D, and the divisions will thus, on the isometrical drawing, represent inches, and the line D b is an isometrical scale of $\frac{1}{12}$.

TO PROJECT A BOX ISOMETRICALLY.

We can now attempt the object, Fig. 121. By means of the set-square of 30°, draw the lines A B and A C; make A B 1′ 6″ long by the isometrical scale (the *line* D b), and make A C 1′ long. At A B and C draw perpendiculars.

Make A D 6″ high, and from D draw lines parallel to A B and A C, and cutting the perpendiculars B and C in E and F.

From E and F draw lines parallel to D F and D E, meeting in G, and this will complete the object as far as the mere block is concerned; and as a rule, it is advisable to project the general block view before attempting the detail.

From D, E, and F, mark off 2″ by scale—viz., h, i, j, k, and from these draw lines parallel to D E, D F, which, intersecting in l, m, n, o, will give the inner edge of the sides of the box, which, it will be remembered, are 2″ thick.

The bottom of the box is also 2″ thick, therefore on the perpendicular A set off A p, and draw p q and p r parallel to A B and A C.

From h, i, j, k draw perpendiculars to cut these lines in s, t, u, v, and from these points draw lines parallel to the sides of the box, cutting perpendiculars drawn from l, m, n, o in w, x, y, z, which will show the junction of the inner sides of the walls and the bottom, and will complete the projection.

TO PROJECT A FOUR-ARMED CROSS.

Fig. 122 shows the isometrical projection of a four-armed cross standing on a square pedestal. Scale, ¼ of an inch to the foot; side of pedestal, 8 feet; height of ditto, 2 feet; complete height of cross, 14 feet.

The pedestal having been projected in a manner precisely similar to that by which the box (Fig. 121) was drawn, carry up the perpendiculars from the angles; make the perpendicular A B 14 feet high, and by drawing lines from B parallel to the sides of the base, complete the top of a block which would contain the entire object; for, as the complete height of the cross is 14 feet, the top of the upright would be in the top of the block; and as the arms are 8 feet long from end to end, their extremities would be in the sides of the block, which may thus represent a glass case exactly containing the cross.

The thickness of the central upright is 2′ 0″; and as the width of the side of the pedestal is 8′ 0″, it follows that if 3′ 0″ be marked off from C to e, from D to d, from C to f, and from E to g, the spaces d e and f g will each be 2′ 0″.

From d, e and f, g draw lines parallel to the sides of the pedestal, which, crossing, will give the lozenge h j i k, which is the plan of the central upright. From d, e, f, g draw perpendiculars to touch the edges of the top of the solid block, B F and B G in l, m, n, o, and lines drawn from these points parallel to the sides will give the top of the central upright. On the front perpendicular A mark off q at 9′ 0″, and P at 11′ 0″ from the bottom, and from these points draw lines parallel to the sides C D and C E. These will give the heights of the top and bottom edges of the arms. But the arms are not so thick as the central upright, being only 1′ 0″; therefore between d and e, and f and g, mark off half a foot from each of the points. This will leave the spaces r s and t u each 1′ 0″ wide. From these draw perpendiculars, which, cutting the lines drawn from p and q, will give the ends of the arms; then draw lines parallel to the sides of the pedestal, cutting h j and h k in v, w and x, y, and from these points draw perpendiculars. From the angles of the ends of the arms draw lines parallel to the sides of the pedestal, cutting these perpendiculars, and these will complete the two arms which are turned towards the front. By producing these lines as shown in the diagram, the portions visible of the opposite arms may be drawn. All further detail will, it is hoped, be rendered clear by reference to the figure.

THE ISOMETRIC CIRCLE.

Projection does not deal with curves as such, but it becomes necessary to find points in rectilineal figures through which the curves pass, then to project the rectilineal figure, and trace the curve through the points so obtained. Thus for isometrical purposes (as in radial perspective) the circle is enclosed in a square (Fig. 123).

Having drawn the circle, describe around it the square A B C D. Draw the diagonals, and also the two diameters, at right angles to each other, meeting the sides of the square in the tangent points E, F, G, H.

The circle not only touches at these four points, but cuts through the diagonals in the points J, K, L, M. Draw lines through each of these points, cutting the sides of the square in j, k, l, m.

Proceeding now to project the circle thus prepared, draw the diagonal C D in Fig. 124 equal to C D in Fig. 123. From C and D draw lines at 30° to C D, intersecting in A and B. This will be the isometrical representation of the enclosing square.

The points E, F, G, H and j, k, l, m are obtained by marking from A the distances A j, j E, E l, and A j, j F, and F m, and drawing lines from these points parallel to the sides of the figure. The intersections J, K, L, M will thus be obtained through which the ellipse, which is the isometrical projection of the circle, is to be drawn. The study may be carried on to the projection of a cylinder, by repeating the operation for the bottom, and joining the intersections by perpendiculars.

The limits of these papers necessarily preclude further illustrations of this branch of projection. Various objects will, however, be delineated on this simple system in the lessons in Technical Drawing devoted to Architectural and Engineering Drawing.

ANIMAL COMMERCIAL PRODUCTS.—XI.

PRODUCTS OF THE CLASS PISCES (*continued*).

In our last lesson it was stated that Cuvier has divided the class Pisces into two sub-classes—

1. *Pisces ossei*, or bony fishes.
2. *Pisces cartilaginei*, or cartilaginous fishes.

The first sub-class of osseous fishes are arranged according to the character of their organs of locomotion into—

Acanthopterygii (Greek *akantha*, a spine, and *pterugion*, a fin), or spiny-finned fishes. Examples: perch, mackerel, and mullet.

* The student is reminded that one dash (′) over a figure means *feet*, and two dashes (″) *inches*; thus 1′ 6″ is one foot six inches.

Malacopterygii (Greek *malakos*, soft, and *pterugion*, a fin), or soft-finned fishes. Examples: herring, salmon, carp, and trout.

Fish constitutes an important article of commerce, furnishing us with immense quantities of oil and an abundance of food. Great Britain possesses a coast-line of 3,000 miles in extent, while that of Ireland is above 1,000 miles, and the greater part of the shores of both islands abound in those species of fish which exist in the largest numbers and yield the most acceptable and nutritious food. Hence a hardy and adventurous race of fishermen have arisen, well supplied with vessels beautifully built, and with materials of the best description. We shall notice only the fisheries commercially most valuable.

Herring (*Clupea harengus*).—This fish appears in vast shoals upon our coasts from July to November, when it forsakes the deeper portions of the sea where it habitually dwells, and comes into the shallow shore water for the purpose of spawning. These shoals, animated by a common impulse, are so enormous that the sea for miles round shines with a silvery lustre from their glittering scales. It is certainly a wise and beneficent law which thus impels certain fish to approach the shore to deposit their ova; for whilst the best means are being taken for the continuance of the species, there is brought within the reach of man an abundant supply of nutritious food, which would otherwise be lost in the depths of the ocean.

The British herring fisheries are principally carried on off Galway, Mayo, in the estuary of the Shannon, at Banbury, and Waterford, in Ireland; at Cardigan Bay and Swansea, in Wales; at Yarmouth, Lowestoft, Hastings, and Folkestone, in England; and on the coasts of Caithness, Sutherland, Ross, Aberdeen, Banff, Moray, and Berwickshire, in Scotland. In the harbour of the small town of Wick, in Caithness, as many as 2,000 boats, each having five or six men, have been congregated at one time during the herring season. Some idea of the extent of this fishery may be inferred from the fact that independently of the home consumption of fresh herrings in 1858, 636,122 barrels of herrings were cured, and 350,204 were exported, valued at upwards of £350,000. In Norway about 600,000 tons of these fish are annually taken and salted. Sweden, Denmark, Holland, and France are also largely engaged in this business.

The *Pilchard* (*Clupea pilchardus*) closely resembles the herring. This fish is very abundant on the coasts of Cornwall during the spawning season in July. Like the herring, it is taken with the net at night. The average annual produce of the Cornish pilchard fisheries is estimated at 21,000 hogsheads, each annually containing 2,500 fish, thus making the total number captured 52,500,000. About 10,521 persons, young and old, are employed, and the capital invested in boats, nets, and cellars for curing, is estimated at £441,215.

The *Sprat* (*Clupea sprattus*), although smaller than the herring, is also very abundant, and furnishes an acceptable supply of cheap and agreeable food. It is caught during the winter months on the coasts of Kent, Essex, and Suffolk, and in such vast quantities as to give rise to the Stow Boat fisheries round the Thames estuary, where they are taken for manure, many thousand tons being sold to the farmers at from 6d. to 8d. per bushel for this purpose. Forty bushels of sprats serve for an acre of land.

Whitebait (*Clupea alba*).—Every one has doubtless heard of the whitebait dinner—or fish dinner, at which whitebait is the chief dish—for so many years annually held at Greenwich by the members of the British Cabinet, and the Lord Mayor and aldermen of London. This little fish, so much prized for its delicious flavour, was formerly regarded as the fry of the shad, while other naturalists maintain that it is quite a distinct species. Günther, an authority of high repute, has recently pronounced that whitebait is the fry of the sprat. It has never been found with matured ova, and therefore does not ascend rivers for the purpose of spawning.

Sardine (*Clupea sardina*) and *Anchovy* (*Engraulis encrasicolus*), both closely allied to the herring, replace that fish in the Mediterranean. The former is taken in great abundance off the shores of Sardinia and Brittany, and packed in small metallic boxes, and is much esteemed as a breakfast relish. The latter, a small silvery fish four or five inches in length, is found on the coasts of France and Portugal. The head and entrails having been removed, it is salted and packed in barrels, and forms the well-known condiment, anchovy sauce. About 140,000 pounds are annually imported.

Mackerel (*Scomber scombrus*).—This well-known and beautiful fish, so valuable as an article of food, is found in abundance on the south and south-east shores of England. Out of the water it soon dies, and becomes quickly tainted. Those caught in the months of May and June are preferred. "Mackerel will bite at almost any bait, hence quantities are taken by hook and line. A slice cut from the side of a mackerel near the tail is a successful lure, or even a strip of red leather or scarlet cloth."* In 1823, 142 lasts of mackerel were taken at Yarmouth—a last is 10,000. This makes a total of no less than 1,420,000 individual mackerel.

Salmon (*Salmo salar*).—This is a soft-finned fish, the body being adorned with spots, and brilliantly coloured, and covered with cycloid scales. The species pass by almost insensible gradations into the clupeoid or herring family. Like the herring they inhabit the sea, and not only approach the land, but ascend the rivers nearly to their sources in order to deposit spawn. For this object the salmon reaches the small streams near the sources of rivers, displaying an amount of perseverance and activity in getting there which is astonishing. Cataracts and weirs ten and twelve feet in height are cleared at a single leap, and should the fish be foiled the first time, it tries again until successful.

After spawning salmon are totally unfit for food. They descend the rivers to the sea with the floods, with which winter usually closes, where they soon recover their condition, and return ample in size and rich in human nourishment, exposing themselves in narrow streams as if Nature intended them as a special boon to man. Such salmon as are taken in estuaries or rivers are, of course, the property of those to whom the estuaries and rivers belong; but latterly considerable quantities have been caught in bays and in the open sea, where the fishing is free. The London markets are principally supplied with salmon sent up from the Tweed, Tay, Don, and Dee, and from Norway, preserved fresh by being packed in ice. The fishing is usually carried on in summer, and when the take is greater than can be conveniently sent off fresh, the residue are salted, pickled, or dried for winter consumption at home, or for foreign markets. Of late years there has been a decrease of salmon in the English and Scotch rivers, the result of poaching and over-fishing. Legislation has done something to remedy the evil. Pecuniary penalties are inflicted on poachers and trespassers; and in Scotland the rivers are shut up—on the Tweed from October 15th to February 15th, and north of the Tweed from September 14th to February 1st.

Cod (*Morrhua vulgaris*).—This valuable fish is spread throughout the seas of Europe from Iceland to Gibraltar, and abounds on the eastern coast of North America from 40° to 60° N. lat., particularly around Newfoundland. It spawns in British waters about February, and is in the best condition as food from the end of October to Christmas. It is amazingly prolific, 9,384,000 ova or eggs having been counted by Leuwenhoeck in the roe of one female. As the cod frequents deep water it can only be taken by long deep sea lines, hooks being fastened at regular distances along their entire length. It is usual to fish for cod in water from twenty-five to forty fathoms in depth, with a hook and line. Cod is voracious, and easily taken with a variety of baits.

The British cod fishery is carried on in a number of places contiguous to the shores of our islands. The most productive home fisheries are those off the coasts of Norfolk, Suffolk, Essex, Lincolnshire, and the Orkney, Shetland, and other islands. The London market is supplied chiefly from the Norfolk and Lincolnshire fisheries. Fresh cod are usually kept alive in welled smacks, and are in this manner brought in good condition from the most distant points of our coasts. The well is capable of holding about fifty score, and receives its water directly from the sea, through perforations in the bottom of the vessel. These vessels are either anchored in a tide-way, or one of the sails is kept set, so as to produce a constant heaving motion, and, in consequence, a perpetual change in the waters of the well. The smacks never go farther up the Thames than Gravesend, as the fresh water intermingles with the salt above that point, and proves destructive to the fish.

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* See article *Fisheries*, "Encyclopædia Britannica," eighth edition.

WEAPONS OF WAR.—V.

BY AN OFFICER OF THE ROYAL ARTILLERY.

BREECH-LOADING SMALL ARMS (*continued*).

We have spoken of the introduction of the Snider-Enfield rifle, the present arm of the British soldier. It is necessary, however, to say something more on the subject of the cartridge for this arm, because it is now recognised that the cartridge really constitutes the soul of any system of breech-loading small arms. The cartridge has been compared to the hinge upon which the system turns; once select a good cartridge, and the difficulty of finding a good rifle is more than half solved. The foundation of a good system is laid, at any rate; and it becomes very much a matter of individual preference whether the cartridge shall be used with this or that breech-action. At this moment there are so many good rifles before the public that the difficulty consists rather in deciding which is the best than in deciding whether any one of them will do.

All these systems have a point of contact in the cartridge. They do not all fire identically the same cartridge, although they could, of course, be made to do so; but they all fire a metallic cartridge—a cartridge which forms a gas-check at the breech, and which has to be withdrawn after firing, and either thrown away or re-filled. There are two great classes of cartridges—those which belong to the class above described, *cartouches obturatrices*, as the French call them, for the reason that they "obturate," or seal the breech at the moment of explosion; secondly, cartridges which are intended to be consumed by the explosion, the arm itself or some portion of the breech mechanism furnishing the gas-check. The English "Boxer" service cartridge, the solid metal cartridge, the stout pasteboard sporting cartridges, are all types of the first class; the Chassepot and needle-gun cartridges are types of the second class. The objections to the second class of cartridges are not inconsiderable. In the first place, the gas escape being taken by the breech of the gun, continued firing tends to make that check less effectual. In the needle-gun, for example, where there is only a mechanical fit of one metal upon another, the "spitting" of fire at the breech is inconveniently great. The same thing occurred in our own cavalry "Sharp" breech-loaders. In the Chassepot the spitting is prevented by an india-rubber ring or washer, which, however, is liable to become injured by use, or hard with frost, or rotten with heat, and which then, of course, fails to fulfil its object. Indeed, we are informed on credible authority that this defect exhibited itself to a very considerable and inconvenient extent during the recent war (1870-1). Again, although cartridges of this class are supposed to be consumed by the discharge, it is a fact that they frequently are not altogether consumed—débris collects and fouls the chamber of the gun, and loading, after a time, becomes difficult. Again, if made very thin, these cartridges are liable to be exploded *en masse* by the accidental ignition of one or two cartridges in their midst.

The list of objections could be largely extended; but the three which we have named will suffice to show that the English military authorities are not without reason in having set their faces against the "consuming" cartridges, and in having adopted the *cartouche obturatrice* for use with our military rifles. For with an obturating cartridge you renew your gas-check each time of firing; you have a cartridge which cannot be exploded by the adjacent explosion of another cartridge; you have a cartridge far more capable, because stronger, of resisting rough usage, transport, and damp; you have a cartridge which, if a miss-fire occurs, can be withdrawn without the use of the ramrod, by simply applying the ordinary extractor; you have a cartridge, also, which is less liable to miss fire, for the reason that its position in the chamber is always determined accurately by means of the projecting metallic base; while with the paper cartridge the position in the chamber varies according to the exact size of the cartridge and of the chamber, the former being, of course, variable, according as the cartridges become deformed in handling and transport.

All these advantages belong to the class of cartridges of which the English service cartridge—the invention of General Boxer, R.A.—forms the best known and most successful type. In this cartridge the maximum of strength is obtained with the minimum of metal. A pasteboard cartridge is inadmissible for military purposes, because it is liable to swell with damp, and is more or less susceptible to injury in other ways. We are, therefore—having narrowed our selection down to the obturating non-consuming class of cartridges, and having eliminated from this class the pasteboard cartridge—left to choose between a cartridge on the Boxer or coil system, and one on the solid metal system. The latter is much more costly than the former, more metal being used in it, and the loss in manufacture being greater. But it is urged that, as the cartridge-case is capable of being fired many times, it is, in the end, cheaper than a once-fired Boxer cartridge. To this there are two answers—first, that the operation of collecting and re-filling empty cartridges is not one which can be carried out by soldiers on service; secondly, that the Boxer construction of cartridge is just as suitable for re-filling as—if not more so than—the solid-metal cartridge. We have ourselves seen these cartridges re-filled and fired as many as thirty-two times. The best authorities are, however, now generally agreed that the operation of re-filling cartridge-cases is not one to be entertained for military purposes, however practicable for sportsmen.

Before proceeding to describe the Boxer, or service cartridge, it may be well to observe in passing that the self-consuming cartridge is not, as is frequently supposed, necessarily cheaper than the metallic cartridge; on the contrary, the Chassepot is a very expensive cartridge, as it is all made by hand. Again, it is generally assumed that loss of time takes place in extracting the empty case of the non-consuming cartridge after firing. This is an error. Even in the Snider the loss of time is inappreciable, and in the improved types of breech-loaders, such as the Martini-Henry, the operation of extracting is combined with that of opening the breech and cocking the arm; there is, therefore, absolutely no loss of time whatever caused by extraction.

The Boxer service cartridge for the Snider rifle (Fig. 3) consists of a case of thin brass, ·005 inch thick, rolled into a cylinder, and covered with paper, by which the coil is cemented together. The coiled case is fitted into a double base-cup of brass, with an iron disc forming the end of the cartridge which abuts against the breech-block of the rifle. The case is secured in its position by means of a rolled paper wad inside, which is squeezed out with great force against the sides of the case. The iron base is attached to the cartridge by means of the copper "cap-chamber," which contains the detonating arrangement; the cap-chamber, being riveted over at each end, holds the base tightly to the cartridge. The ignition is effected by means of a percussion-cap, resting on a small shouldered brass anvil. To explode the cap, it is necessary that the crown of the cap should be indented (by the striker of the rifle, for example), when the detonating composition is brought into contact with the anvil, and the flash passes through the fire-hole at the bottom of the cap-chamber to the powder in the case. The top of the cartridge is closed by means of a small quantity of wool, over which is fitted the bullet. This bullet has four grooves or *cannelures* round it, which serve to carry the wax lubrication, which in this ammunition is distributed in a thin film around the bullet. The construction of the bullet is peculiar, the head as well as the base being hollowed out. The base is hollowed out for the same reason as in the bullet for the muzzle-loading Enfield—viz., for the insertion of a clay plug, by which the bullet will be expanded into the grooves of the rifling. The head of the bullet is made hollow, in order to give the necessary length to the bullet without increasing the weight. The following are the details:—Length of bullet, 1·065″; diameter (without lubrication), ·573″; weight, 480 grains. Length of cartridge, 2·445″; weight, 1 oz. 10 drs. 20 grs.; charge, 70 grains. This bullet, although an ingenious contrivance for overcoming the difficulties inherent in a large bore slow-twist rifle, is the least satisfactory part of this ammunition; and repeated changes have been made, and innumerable experiments, with a view to the adoption of another bullet for this arm. Hitherto the results have been attended with little marked success, and all that can be said is that the present bullet gives an accuracy and general shooting power about equal to that of the old Enfield, and superior to it in one respect—viz., that the wounds inflicted by the hollow-headed bullet are much more severe than those inflicted by the solid-headed bullet.

The conversion of the muzzle-loading arms may therefore be said to have fully answered its purpose. Let no one depreciate the Snider rifle. It is an admirable weapon, and, taken all

round, superior to most of the breech-loading rifles in the hands of other military powers. It is simple, durable, economical, capable of a rapidity of fire of from twelve to eighteen shots per minute, according to the skill of the firer; the extraction of the empty case is effected with ease and rapidity; the ammunition is exceedingly durable, strong, little susceptible to injury by damp, and as cheap, probably, as any equally serviceable ammunition can be made. It is important to notice that one characteristic feature of great excellence in this cartridge is the coiled case. The action of firing causes the case to expand immediately against the sides of the chamber; and this expansion is followed by an instantaneous contraction, by means of which the withdrawal of the empty shell is greatly facilitated. Also, the arrangement of base is especially noteworthy—the solid end, which gives great stability to a part of the cartridge where strength and resistance are required, and which likewise serves for the claw of the extractor to take hold of. The double cup affords the necessary strength round the back end of the cartridge, the part upon which the greatest strain comes, especially if the block of the rifle should happen not to fit very

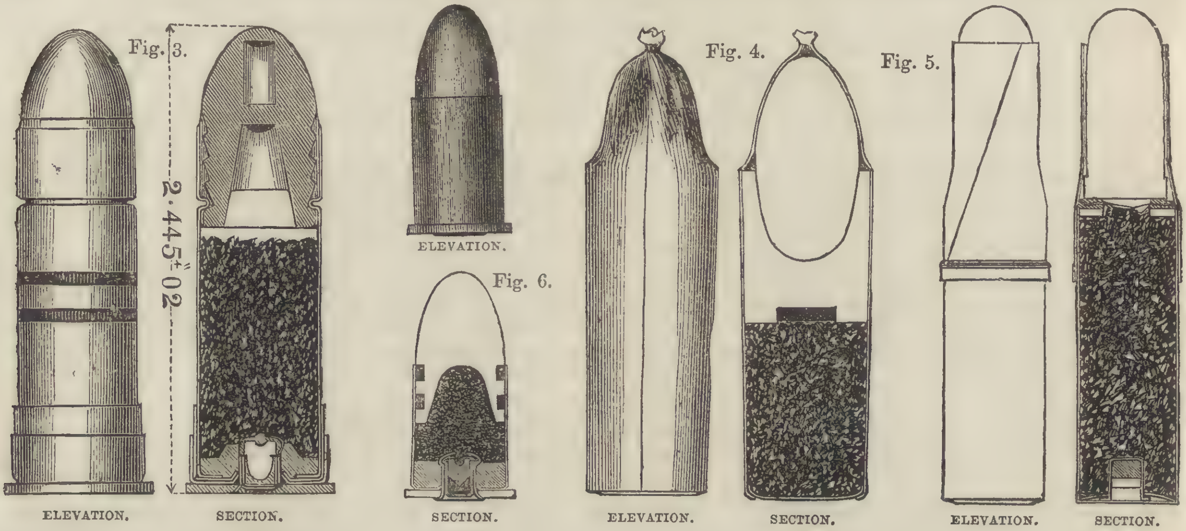

Fig. 3.—BOXER CARTRIDGE FOR SNIDER RIFLE. Fig. 4.—AMMUNITION FOR PRUSSIAN NEEDLE GUN. Fig. 5.—AMMUNITION FOR FRENCH CHASSEPOT. Fig. 6.—BOXER CHARGE FOR BREECH-LOADING REVOLVER.

accurately, or if, from any other cause, the cartridge should be subjected to undue strain round the rim.

Having given a drawing of our own service cartridge, we think that the accompanying drawings of the cartridges for the Prussian needle-gun (Fig. 4) and the French Chassepot (Fig. 5), with the following details as to dimensions, weight, etc., may be of interest for comparison. These are, for Prussian needle-gun:—Length of bullet, 1·08″; diameter, ·533″; weight, 480 grs. Length of cartridge, 2·44″; weight, 1 oz. 6 drs. 20 grs.; weight of charge, 66 grs. For French chassepôt:—Length of bullet, 1·″; diameter, ·463″; weight, 380 grs. Length of cartridge, 2·64″; weight, 1 oz. 2 drs. 2 grs.; weight of charge, 85 grs.

The needle-gun cartridge is made of paper. Rotation is given to the bullet by means of a paper sabot, which, being slightly larger than the bore, is forced into the rifling. The bullet thus does not touch the bore at all, but is spun by means of the sabot. This method is a clever plan for obtaining the advantages of a large bore, in respect of shortness of cartridge, prompt ignition of the charge, etc., while preserving the advantages of a small bore as far as the bullet is concerned. But the needle-gun is not at all a satisfactory arm, considered as an arm of precision or as a breech-loader. The liability, under the latter head, to escape of gas at the breech, has been before remarked upon; in addition, the mechanism is defective in some important particulars. As an arm of precision, the weapon is feeble. The velocity imparted to the bullet is small—only about 1,000 feet per second, as against 1,390 for the Chassepot, 1,260 for the Snider, and 1,335 for the Martini-Henry; the trajectory is consequently high, the range is small, and the accuracy of the weapon leaves much to be desired—so much, indeed, that we find the Prussians have taken the advantage of the large number of Chassepots which have fallen into their hands to arm some of their troops with them. But the Chassepot, as we shall see when we compare it hereafter with the Martini-Henry, is far from a satisfactory arm. The ignition of the needle-gun cartridge is effected by means of a small patch of detonating composition placed at the back of the sabôt, into which the needle penetrates when the arm is fired.

The Chassepot cartridge is made of thin paper, covered with thin silk, the latter being intended to secure the blowing out of the whole of the débris of the consumed cartridge when the arm is discharged. The ignition is effected by means of a percussion-cap, into which the needle strikes, disturbing the detonating composition, the flash passing through holes in the crown of the cap. The cap, it will be observed, is presented to the striker in the opposite direction to the cap in the Boxer cartridge, and the ignition is effected by means of a needle, instead of with a blunt piston. To prevent the gas from the exploded cap escaping backwards, the mouth of the cap is covered with a thin disc of india-rubber, through which the needle passes. Sometimes this india-rubber comes back with the needle, interfering with its action. This is one of the minor defects of the system. There are several other defects too numerous to be here enumerated, but to which the French are now only too fully alive.

Other means of igniting breech-loading cartridges have been designed. There is the well-known "pin-fire," so common in sporting cartridges, in which a blunt pin which projects from the cartridge, and one end of which rests in a percussion-cap inside the cartridge, is driven down by the hammer of the gun. There is also the "rim-fire" cartridge, a common American form, in which the fulminate is enclosed in the rim of the base of the cartridge. This method is objectionable on many accounts. Then, of "central-fire" cartridges, of which the Boxer is an example, there are infinite varieties; but the system of cap and anvil is the one most generally in vogue. It is hardly possible to doubt, however, that this detail will in time be considerably simplified and improved upon.

We will mention in this paper one other description of breech-loading cartridge, and one only—namely, the service cartridge for the breech-loading revolver. The construction of this cartridge is sufficiently exhibited in Fig. 6. This ammunition has now entirely superseded the old skin or paper revolver cartridge, which was in vogue until a few years ago. The pistol with which it is used in Her Majesty's service is an Adams' revolver—a simple, strong, quick, serviceable weapon. In our next paper we propose to treat of the Martini-Henry breech-loader and its ammunition, and to bring the subject of Small Arms to a conclusion.

VEGETABLE COMMERCIAL PRODUCTS.—IX.

NUTS (*continued*).

WALNUT (*Juglans regia*, L.; natural order, *Juglandaceæ*).—This fine tree is too well known to need description. It grows not only in England, but over the whole of Europe, and in Asia. It is especially abundant in Circassia, where it is extensively cultivated. There is a considerable number of English walnuts in the market, as the fruit ripens well in the southern parts of this country. We receive about 30,000 bushels of foreign walnuts annually, chiefly from Germany, France, and Italy. Walnuts will not bear a long voyage without being kiln-dried, a process which certainly spoils them.

HICKORY AND PECAN NUTS.—We receive from the United States, in small quantities, the hickory nut (*Carya alba*, Nutt.), and the pecan nut (*Carya olivæformis*, Nutt.), both of which belong to the same natural order, *Juglandaceæ*. These nuts have kernels very similar to those of the walnut, but their shells are very different. The hickory nut is smooth, whitish, marked on its exterior with three or four elevated ridges, extremely hard, and smaller than the walnut. The pecan nut is about the size of an olive, which it resembles in shape, as implied by its specific name; its colour is a light reddish-brown.

BRAZIL NUT (*Bertholetia excelsa*, Humboldt; natural order, *Lecythidaceæ*).—Large fine trees, often 120 feet in height, and growing abundantly in the Brazilian forests. The nuts are closely packed in a hard woody capsule, to the number of twelve or twenty. This capsule is nearly round, but slightly pear-shaped, and is so hard and heavy that when ripe it is dangerous to pass under the trees, for a human head is not thick enough to escape fracture if it be struck by one of these fruits in falling. The capsules open at the top by a circular lid, whence they have been called monkey-pots. Sometimes, as soon as the falling capsule strikes the ground it bursts open, and this is at once the signal for an amusing scramble amongst the monkeys, who, keeping sentinel on a hundred branches, instantly swing themselves from tree to tree by the help of their prehensile tales, until they arrive at the spot, and then fight furiously for the coveted nuts. The Indians, in order to obtain the nuts, pelt the monkeys with stones, who in return gather the capsules to hurl at their opponents. In this manner large quantities are collected and transferred to boats, and thence to vessels. We receive from the Brazils annually not less than 50,000 bushels of these nuts.

THE WALNUT-TREE (JUGLANS REGIA).

CHESTNUT (*Castanea vesca*, L.; natural order, *Cupuliferæ*).—The chestnut-tree is a native of Great Britain and the temperate parts of Europe, but the nuts not coming to perfection in this country, we import nearly all that we use from Spain, whence they are usually called Spanish chestnuts. Upwards of 50,000 bushels are annually imported. Although not very nutritious, chestnuts are much more easy of digestion when roasted. The larger and better sort called Marones are the produce of Italy, France, Switzerland, and of some parts of Germany.

SWEET ALMOND (*Amygdalus communis*, L.; variety, *dulcis*; natural order, *Rosaceæ*).—The almond-tree, a native of the warm parts of Asia, and of the coasts of Barbary, is now cultivated to some considerable extent in Southern Europe, especially in Italy and Spain. It grows to about the size of a common plum-tree. The cortex or outer envelope of the fruit is not succulent like the peach (*Amygdalus Persica*, L.), to which the almond is allied, but hard, green, and juiceless, so that when growing it looks not unlike an unripe apricot; when fully ripe this green covering splits, and the almond in its rough shell drops out. There are two well-marked varieties of the sweet almond. (1.) The Jordan almonds, the finest and best of the sweetest variety; these, notwithstanding their Oriental name, we receive from Malaga, imported without their shells. (2.) The Valentia almonds, which are broader and shorter than the Jordan variety, and usually imported in the shell. England receives yearly about 500 tons of this fruit, which is usually eaten with raisins.

BITTER ALMOND (*Amygdalus communis*, L.; variety, *amara*).—This variety comes to us from Barbary, in Northern Africa, where it forms a staple article of trade. It is principally used for its oil, which imparts a pleasant flavour to confectionery. This almond is smaller and much rounder than the two preceding varieties of sweet almond, and very bitter to the taste. The annual imports amount to about 300 tons.

THE PALM FAMILY (NATURAL ORDER PALMACEÆ).

The palms, next to the cereal grasses and sugar-cane, are the most valuable order of food-plants. They are, however, of far greater importance in the countries where they are produced than in our own, furnishing as they do to the inhabitants of

those countries food, shelter, and clothing. The most useful plant of this order is

The Cocoa-nut Palm (*Cocos nucifera*, L.).—This palm supplies the natives of the countries in which it grows with clothing, food, medicine, houses, and every description of domestic utensil. The aspect of the tree is very imposing. Its stem is tall and slender, without a branch, and at the top are seen from ten to two hundred cocoa-nuts, each as large as a man's head; over these are the gracefully drooping, green, glossy, and beautiful fronds. "The blessings it confers are incalculable. Year after year the islander reposes beneath its shade, both eating and drinking of its fruit; he thatches his hut with its boughs, and weaves them into baskets to carry his food; he cools himself with a fan plaited from the young leaflets, and shields his head from the sun by a bonnet of its leaves; sometimes he clothes himself with the cloth-like substance which wraps round the base of the stalks, whose elastic rods, strung with filberts, are used as a taper. The larger nuts, thinned and polished, furnish him with a beautiful goblet, the smaller ones with bowls for pipes; the dry husks kindle his fires, their fibres are twisted into fishing-lines and cords for his canoes. He heals his wounds with a balsam compounded from the juice of the nut, and with the oil extracted from it embalms the bodies of the dead. The noble trunk itself is far from being valueless. Sawn into posts, it upholds the islander's dwelling; converted into charcoal, it cooks his food; and supported on blocks of stone, rails in his lands. He impels his canoe through the water with a paddle of the wood, and goes to battle with clubs and spears of the same hard material."*

The cocoa-nut palm grows by the sea-side in most tropical countries, and is usually the first plant to establish itself on the newly-formed coral reefs in the Pacific and Indian Oceans. It is abundant throughout the South Sea Islands. The fibrous outer covering of the nut, when macerated and prepared, is termed *coir*, a substance extensively employed for making ropes, mats, and stuffing for cushions. Large quantities of oil are obtained from the nut, after it has been ground into a rough meal, called in Ceylon *coperah*. This oil has of late years been in great demand in England for the manufacture of composite candles and soap. Marine soap, so called because it washes linen with sea-water, is made from cocoa-nut oil. This nut is used largely in confectionery. The cocoa-nut forms a considerable article of export from many of our colonies; 3,500,000 were exported from Ceylon in 1847, whence coir and coperah are also largely shipped.

VII. MISCELLANEOUS FOOD PLANTS.

Onion (*Allium cepa*, L.; natural order, *Liliaceæ*).—The onions of Spain and Portugal and the south of France are superior to our common garden onion, larger, and more succulent; we therefore import them from those countries in chests and boxes to the amount of about 700 or 800 tons.

Soybean (*Soja hispida*; natural order, *Leguminosæ*).—A sauce or catsup, as thick as treacle and of a clear black colour, called soy, which is much esteemed, is made from the beans of this plant by the Chinese, and sent to us from India in considerable quantities. From 500 to 600 gallons are annually imported.

Truffles (*Tuber cibarium*; natural order, *Fungi*).—These remarkable fungi grow beneath the soil, generally in beech woods, in this country somewhat sparingly, but more plentifully in France and Italy. The truffles of commerce, besides the above species, include several others, all of which are edible, and highly prized for their delicate flavour. In form the truffle is round, its surface in some species smooth, in others warted and tuberculous; the colour, dark-brown outside, and brown, grey, or white within. They generally grow at the depth of five or six inches. Dogs are trained to scent them out, and sows are also employed for the same purpose. We receive them from France and Italy preserved in oil. They are used generally in sauces and soups, and as stuffing for poultry.

Morel (*Morchella esculenta*, Dill.).—This is one of the few fungi found in this country which may be eaten with safety. The stipes or stalk is hollow, from two to three inches high; the pileus or cap is spheroidal, hollow within, and marked on the surface with numerous areolæ resemble a honeycomb in structure; the colour whitish.

The morel is usually found abundantly where trees have been burnt, a fact which led in Germany to the practice of firing the forests for the sake of the morels, a practice so injurious that it became necessary to suppress it by law. This fungus occasionally occurs in woods and orchards in England, whence it finds its way to our markets; it is found to be very valuable for cookery purposes, but is more frequently used in a dry state for sauce than when fresh. We import the greater proportion of the morels used in England from Italy.

Carrageen or Irish Moss (*Chondrus crispus*; natural order, *Algæ*).—This is a very common plant on the rocky coasts of Ireland and Great Britain. The frond is tufted, fixed to the rock by a hard scutate base, dichotomous, the segments linear, wedge-shaped, frequently crisped and curled at the edges. The whole plant looks like yellow parchment.

Carrageen or Irish moss is sold by all druggists and herbalists in the United Kingdom. It contains an abundance of gelatine, and is extensively used for feeding cattle, and for forming a light nutritive jelly for invalids, nearly the whole weight of the plant being convertible by boiling into the required substance. Carrageen moss is sometimes used in manufactories for dressing silks. Immense quantities of it are annually brought to England from the Irish coast, and from Northern Europe. A preparation of this moss is now sold under the name of Sea-Moss Farine, which is coming into very general use. The moss is apparently dried, and then ground or crushed into a kind of meal, resembling fine sand. The jelly obtained from this plant is made far more quickly from the meal than it is by boiling the moss in an entire state.

We have now considered the principal, if not all, of the plants used for food, and some other purposes in commerce, in the lessons that have been brought under the notice of the reader. In our next lesson on this subject we shall commence a review of plants that are of importance in medicine and many of the industries of the United Kingdom, commencing with textile plants, or those from which we derive materials for clothing and cordage.

* Melville's "Adventures in the South Seas."

APPLIED MECHANICS.—VI.

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COMMON TOOLS: THE HAMMER, SAW, FILE, AND CHISEL.

THE HAMMER.

This very well-known tool is a remarkable mechanical power. The study of its action is important, as it depends on some principles of the greatest consequence. We shall commence by an explanation of these principles, and we shall then apply them to certain different forms of hammer, reserving, however, the important subject of the steam-hammer for a separate lesson.

We shall suppose that a hammer is employed for driving a nail into wood, and let us examine what is the resistance to be overcome by the nail, and compare it with the power which is applied to the hammer.

In considering this subject, it is necessary to understand the structure of wood. Wood is composed of multitudes of fibres placed side by side. In this it differs from stone, which is a multitude of particles merely attached together. This constitution of wood is the cause of many of its peculiar properties. The fibres are extremely tenacious in themselves, but they adhere together with comparatively weak force. This produces what is called the grain in wood. If I take a piece of pine one foot long and one inch square, I should find it impossible to break it when the fibres—that is, the grain—run along the length of the wood; the reason of this is, that to break the piece the fibres would have to be torn across, and enormous force would be required. But if I take a piece of pine of the same dimensions, in which the grain runs across the wood, I find that it is broken with comparative ease. The reason is that in this case the fibres have not to be torn asunder, but only separated, and the force of adhesion is not great. In different woods, the grain varies, the fibres being much more compact in some cases than

in others. Splitting of wood is a separation between contiguous fibres. In fact, a piece of wood is to some extent analogous to a rope, the fibres in each being placed side by side; the difference lies in this, that in the first place the fibres of wood are not twisted like those of the rope, and in the second place that the fibres of the wood adhere together, while those of the rope do not. The fibres of wood are also short. Wrought-iron, when rolled into bars, presents somewhat of a fibrous structure in the direction of its length; this is seen when one of these bars is torn asunder.

The nail has two completely different resistances to overcome. It has, in the first place, to compress the fibres of the wood, so as to make a hole for its entry. After it has entered, as it is somewhat of a taper form, while the point is dividing the fibres and compressing them on each side, the sides of the nail must still be compressing the fibres, as the hole has to be made larger and larger, to admit the tapering nail. One part, then, of the force of the hammer is expended upon compression of the fibres; but there is another force to be overcome by the nail, and that is the friction against the sides of the hole—the nail is pressed with great force against the wood, and there is, therefore, a great deal of friction produced. The relative amounts of these forces it is not easy to determine; it is probable that in hard woods the first is the most important, while in very soft woods the proportion which the latter bears to the former is doubtless greater, but both added together produce a very large amount of force, which has to be overcome by the blows of the hammer.

Before driving a nail into wood it is often usual to bore a hole for it with a bradawl, and the exertion of making a hole is a measure of the resistance produced by compression of the fibres. The extremity of the bradawl is bevelled, as shown in Fig. 1. This bevelled edge must, as every one knows, be placed at right angles to the grain of the wood. When pressed downwards it divides the fibres, and then compresses them in the direction of the length of the fibres. In so doing, there is little tendency to split the wood, for the wedge-shaped extremity is never employed in forcing the fibres apart. But if the edge of the bradawl be placed parallel to the fibres, then as the wedge enters it forces the fibres apart; and if it be easier to split the wood than to compress the fibres together, the former catastrophe happens. The resistance of the wood to splitting is measured by the area of the surfaces which would have to be separated; hence in the middle of a large piece of timber splitting will not occur, however the bradawl be introduced, because, though the resistance of the fibres to compression is still as great as before, yet the resistance to splitting has been increased to be greater than the resistance to compression.

Fig. 1.

The hole having been bored for the reception of the nail, the amount of work to be done by the hammer is diminished until the nail completely fills the hole, and then, of course, the further resistance is the same as if no hole had been bored.

In order to express the amount of force which the hammer exerts upon the nail, we must consider what weight must be laid upon the head of the nail in order to force it into the wood. This force must evidently be enormous. A nail requires a very large force to pull it out, when friction alone is retaining it, and to force it in must of course require a very much larger force. We may, therefore, be assured that a force at all events of some hundredweights would have to be laid upon the head of a two-inch nail, in order to force it into the wood. It is, of course, meant that the pressure of this weight is to be simply borne by the nail: we do not mean that the head is to receive a blow with this amount; it would, of course, not be possible to place a heavy load on the head of the nail directly; we must produce the effect by means of levers, or some similar contrivance.

Now the head of the hammer must be capable, when it delivers a blow upon the head of the nail, of developing a force for a short time equal to the continued pressure that would be produced by a load of many hundredweights; hence the hammer is a mechanical power, for it transforms the power of the hand into a far larger force. What is the cause of this property of the hammer? It depends upon a remarkable force called the force of inertia, and may also be viewed in connection with the principle of work to which we have already so often referred. We shall first consider it in the former aspect, and afterwards in the latter.

To set a body in motion requires the exertion of force. This is so evident, following as it does from the definition of force, that it is not necessary to dwell upon it. To set the head of the hammer in motion the force of the hand is required. But when a body has been set in motion, it requires force to stop it. This is nearly as evident as the former statement. When a railway train is in motion, it would require a prodigious force to stop it. When a stone drops upon the ground, it is stopped by the force of reaction which the ground exerts upon it. In short, to change the condition of a body as to arrest a motion requires the exertion of force. Now action and reaction are equal and opposite; this is a profound law of Nature not always easy to comprehend. In the present case it asserts that when any force acts upon a body to stop it, the body reacts with an equal force upon the body which endeavours to stop it.

Hence, when the head of the hammer comes into contact with the nail, the head of the nail acts upon the hammer, and the hammer reacts upon the nail. This force of reaction may be enormously great. The amount of the force depends upon the amount of motion which the nail makes. If the nail move but a very small way, the force is great; but if the nail yields easily, the force is comparatively small. This will be evident from the obvious circumstance, that a rapidly moving body exerts a prodigious force of reaction upon any body which endeavours to stop it suddenly, but if the body be stopped gradually it exerts a much less force.

But the action of the hammer may be viewed in another way, which will perhaps make the matter clearer. Work or energy, as we have already explained it, may be stored up in a moving body. Thus, for example, a cannon-ball when in motion has a quantity of energy imparted to it by the explosion of the gunpowder; this energy is stored in it until the cannon-ball meets a wall or other obstacle, the energy is then instantly transferred to the destruction of what is opposed to it, and the ball, having spent its energy, comes to rest. That work is actually in the ball may be at once realised, if we remember that a cannon-ball might be shot straight up into the air. Thus, suppose a ball of 100 lb. weight ascended 1,000 feet, the ball contained sufficient energy to accomplish

$$100 \times 1{,}000 = 100{,}000$$

foot-pounds of work. Whatever be the moving body, the way to estimate the quantity of energy it contains is to see how high in the air its velocity would raise it.

If a body were moving with a certain velocity, the laws of Mechanics tell us that the height to which it would ascend if projected vertically upwards with that velocity is

$$\frac{(\text{velocity})^2}{64}$$

If, therefore, we multiply this height by the mass of the body, we have as product the number of units of work that the body is capable of doing before it comes to rest.

Let us apply these considerations to the case of the hammer. We shall suppose a hammer, the head of which weighs 1 pound. Now the head of the hammer is not merely allowed to fall upon the nail, but is impelled downwards upon it by a considerable velocity. We may suppose, at all events, that when the head of the hammer reaches the nail, it is at that instant moving with a velocity of 20 feet per second. Now, by the rule already given, a body projected vertically upwards with a velocity of 20 feet per second would ascend to a height—

$$\frac{(20)^2}{64} = \frac{400}{64} = 6{\cdot}2 \text{ feet.}$$

This is certainly within the mark, for it is probable the velocity exceeds 20 feet. The quantity of work stored in the hammer is, then, sufficient to raise 1 lb. 6·2 feet high, or, in other words, the hammer contains 6·2 units of work. All this work is expended upon the nail, and let us suppose that the nail is forced into the wood one-tenth of an inch by one blow. The nail must then react upon a hammer with a sufficient force to consume the entire 6·2 units of work when the hammer moves through one-tenth of an inch.

Let F be the force with which the hammer and nail react on each other, then the number of units of work done in forcing the nail into the wood is

$$F \times 0{\cdot}1'' \div 12;$$

but this must be equal to the number of units of work which the hammer expends, hence we must have

$$F \times 0{\cdot}1'' \div 12 = 6{\cdot}2,$$

from which we find

$$F = 744.$$

Hence the pressure exerted on the head of the nail is at least 744 lb. This is a very large force, equal to a third of a ton.

But supposing the nail had only entered 0·05″, we shall easily find by the same process that the pressure exerted is 1,488 lb. Hence we see that, according as the wood is harder—that is, according as the nail enters less at each stroke—the force of the blow becomes greater. Thus the hammer is a mechanical power most admirably adapted for the purposes it fulfils.

The pile-driver is an example of the hammer which is well adapted to illustrate these principles. A pile is a large piece of timber, shod at one end with an iron point, and provided with a hoop of iron surrounding it at the other end; the pointed end is forced into the ground by means of heavy blows delivered upon the other end. The mode in which these blows are given is extremely simple. A massive iron weight, called a "monkey," slides up and down on a vertical frame, by means of a lifting crab or a steam-engine; this weight is raised to a considerable height, and then let fall upon the head of the pile; these blows are repeated until the pile has been driven so far that the blows produce but little effect. Now, if we suppose that the mass of the monkey in a pile-engine is 500 lb., and that the monkey is raised to a height of 20 feet, and then allowed to fall, the number of units of work that have been stored up in the monkey, and which it is therefore capable of exerting, is

$$500 \times 20 = 10{,}000.$$

Hence 10,000 units of work will be expended upon the pile. Now suppose that the pile be only driven 1″ into the ground by the blow. Let us calculate the pressure which has been exerted. Since 1″ is one-twelfth of a foot, we have for the force F

$$\tfrac{1}{12} F = 10{,}000; \quad \therefore F = 120{,}000.$$

Hence the pile is urged downwards for the space of 1″ by a pressure of 120,000 lb., that is, a force of upwards of 50 tons.

When the pile has been driven some distance, it moves less and less under each blow; consequently, as we have already explained, the magnitude of the force which each blow produces is increased. When the pile "refuses," as it is technically termed, we are then assured that it can withstand a force of enormous magnitude, and, therefore, is capable of supporting the buildings or whatever else the pile may be intended to sustain.

THE SAW.

The ancients probably employed the simple process of splitting for the purpose of dividing timber; but such a process is wasteful, both of material and time. This rude method has been replaced by the saw, which, in different forms, is doubtless the most important tool used in the working of wood. We shall afterwards return to the subject of the machinery used in saw-mills, and therefore we shall not here discuss the circular saw and other special applications of the saw, but shall confine ourselves to a general sketch of the process of sawing.

We have already described the structure of wood as consisting of multitudes of fibres placed side by side. In sawing a piece of wood with the grain, the teeth of the saw tear away these fibres without necessarily cutting them across; in sawing against the grain, however, the fibres have actually to be divided. This is the reason why a saw used for cutting along the grain, called a hand-saw, has larger teeth than a saw which is used for cutting against the grain, called a tenon-saw. The method of sawing is also applicable to other materials besides wood. Marble and other soft stones are frequently cut by saws specially adapted for the purpose. In these cases the sawing is really accompanied by a grinding process. The particles of stone which are removed are comminuted into very small particles.

Some very valuable remarks upon saws and other tools are to be found in Holtzappfel's treatise on "Turning and Mechanical Manipulation." From this work the following account is condensed:—

"The blade of the saw is a thin plate of steel rolled of equal thickness; the teeth are then punched along its edge previously to the blade being hardened and tempered. After this process the saw is flattened by hammering. The blade is then ground upon a grindstone of considerable diameter, and principally crossways, so as to reduce the thickness of the metal from the teeth towards the back. When, by means of the hammer, the blade has been rendered of uniform tension or elasticity, the teeth are sharpened with a file, and slightly bent to the right and left alternately, in order that they may cut a groove so much wider than the general thickness as to allow the blade to pass freely through the groove made by itself. The bending is called the 'set' of the saw. The angles of the points of the saw-teeth are more acute in proportion to the softness of the material to be sawn.

"In using the hand-saw, the left hand is applied to the board, in order that the end of the thumb may be placed just above the teeth and against the smooth blade of the saw, to guide it to the line. The saw is then drawn backwards and forwards a few times with light pressure, to make a slight notch. In the first few strokes the length and vigour of the stroke of the saw are gradually increased, until the blade has made a cut of two to four inches in depth, after which the entire force of the right arm is employed, the saw is used from point to heel, and, in extreme cases, the whole force of both arms is used to urge the saw forwards.

"In order to acquire the habit of sawing well, or, in fact, of performing well most mechanical operations, it is desirable to become habituated to certain definite positions; thus, in sawing, it is better the work should as often as practicable be placed either exactly horizontal or vertical; the positions of the tools and the movements of the person will then be constantly either horizontal or vertical, instead of arbitrary and inclined."

THE FILE.

This useful tool depends for its action upon the same principles as the action of the saw. The file is composed of a piece of steel which has first been roughened by a special process called file-cutting, and then rendered intensely hard. The file is used for removing small quantities of metal from a surface. The work is held firmly in a vice, and the file is moved backwards and forwards by the workman. Simple as the process of filing appears to be, a great deal of skill is demanded in order to do work with it as it should be done. The ridges on the file detach small particles of the work; the finer the file, the smaller are the particles which are removed. Polishing with rouge is in reality a process of filing; the particles of rouge are extremely small and extremely hard, and they remove extremely small particles of the surface, and thus polish it, for a polished surface is not absolutely smooth. When magnified, it is seen to be rough, but the irregularities are very small; the rouge removes all irregularities above a certain magnitude.

Holtzappfel thus describes the manufacture of files:—"The pieces of steel or the blanks intended for files are forged out of bars of steel that have been either tilted or rolled as nearly as possible to the sections required, so as to leave but little to be done at the forge; the blanks are afterwards annealed with the greatest caution, so that in none of the processes the temperature known as the blood-red heat may be exceeded. The surfaces of the blanks are now rendered accurate in form and quite clean in surface, either by filing or grinding. In Warrington, where small files are made, the blanks are mostly filed into shape, as the more exact method. In Sheffield, it is customary, in the manufacture of large files, to grind the blanks on the grindstone as the more expeditious method; but the best of the small files are here also filed into shape, and in some few cases the blanks are placed in the planing machine for those called *dead parallel* files, the object being in every case to make the surface clean and smooth. The blank before being cut is slightly greased, that the chisel may slip freely over it, as will be explained. The file-cutter when at work is always seated before a square block or anvil, and he places the blank straight before him, with the tang towards his person; the ends of the blank are held down by the leather straps or loops, one of which is held fast by each foot.

"The ridges are cut by means of a chisel, which, for larger files, at Sheffield, is 3 inches long, $2\frac{1}{4}$ inches wide, and has a cutting-edge at an angle of 50°. The first cut is made at the point of the file; the blow of the hammer upon the chisel causes the latter to indent and slightly drive forwards the steel, thereby throwing up a trifling ridge or burr. The chisel is im-

mediately replaced upon the blank, and slid from the operator until it encounters the ridge previously thrown up, which arrests the chisel, or prevents it from slipping further back, and thereby determines the succeeding position of the chisel. The heavier the blow the greater the ridge, and the greater the distance from the preceding cut at which the chisel is arrested. The chisel having been placed in its second position is again struck by the hammer, which is made to give the blows as nearly as possible of uniform strength; and the process is repeated with considerable rapidity and regularity, sixty to eighty cuts being made in one minute, until the entire length of the file has been cut with inclined, parallel, and equidistant ridges, which are collectively denominated 'first course.' So far as this one face is concerned, if the file is intended to be single-cut, it would then be ready for hardening. Most files are, however, double-cut, or have two courses of chisel cuts; and for these the surface of the file is now smoothed, by passing a smooth file once or twice along the face of the teeth, to remove only so much of the roughness as would obstruct the chisel from sliding along the face in receiving its successive positions, and the file is again greased. If the file is flat, and to be cut on two faces, it is now turned over, but to protect the teeth from the hard face of the anvil a thin plate of pewter is interposed. In cutting files they almost always become more or less bent, and there would be danger of breaking them if they were set straight while cold; they are consequently straightened whilst they are at the red heat, immediately prior to their being hardened and tempered. Previously to their being hardened, the files are drawn through beer-grounds, yeast, or other sticky matter, and then through common salt, mixed with cows'-hoof, previously roasted and pounded, and which serves as a defence to protect the delicate teeth of the file from the direct action of the fire. The compound likewise serves as an index of the temperature, as on the fusion of the salt the hardening heat is attained. The file thus prepared is gradually raised to a dull red, and is then straightened with a leaden hammer on two small blocks of lead; the temperature is afterwards increased until the salt just fines, when the file is immediately dipped in water. The tangs are next softened, to prevent their fracture: this is done by immersing the tang in a bath of melted lead. The tang is afterwards cooled in oil. When the file has been cleaned it is fit for use."

THE CHISEL.

This tool depends for its action upon principles very different from those of the saw or file. We take the chisel as the type of a cutting tool, and we must first consider in what the act of cutting consists. We shall again borrow from the admirable authority (Holtzappfel) already referred to:—

"If we drive an axe or a thin wedge into the centre of a block of wood, it will split the same into two parts, through the natural line of the fibres, leaving rough uneven surfaces, and the rigidity of the mass will cause the rent to precede the edge of the tool. The same effect will partially occur when we attempt to remove a stout chip from off the side of a block of wood with the hatchet, adze, paring-knife, chisel, or any similar tool. So long as the chip is too rigid to bend to the edge of the tool, the rent will precede the edge, and with a naked tool the splitting will only finally cease when the instrument is so thin and sharp, and it is applied to so small a quantity of the material that the shaving can bend to the tool, and then only will the edge be cut, or will exhibit a true copy of the edge of the instrument, in opposition to its being split or rent, and consequently showing the natural disruption or tearing asunder of the fibres."

"For paring a large or nearly horizontal surface, the adze is the proper instrument to be employed. The tool is held in both hands, whilst the operator stands upon his work in a stooping position; the handle being from twenty-four to thirty inches long, and the weight of the blade from two to four pounds.

"The adze is swung in a circular path almost of the same curvature as the blade, the shoulder-joint being the centre of motion, and the entire arm and tool forming as it were one inflexible radius. The tool, therefore, makes a succession of small arcs, and in each blow the arm of the workman is brought in contact with the thigh, which thus serves as a stop to prevent accidents. In coarse preparatory works, the workman directs the adze into the space between his two feet; he thus surprises us by the quantity of work removed. In fine works he frequently places his toes over the spot to be wrought, and the adze penetrates two or three inches beneath the sole of his shoe, and he thus surprises us by the apparent danger yet perfect working of the instrument, which, in the hands of the shipwright in particular, almost rivals the joiner's plane; it is with him the nearly universal paring instrument, and is used upon works in all positions."

"The chisel when inserted in one of the several forms of stocks or guides becomes the plane, the general objects being to limit the extent to which the blade can penetrate the wood, to provide a definitive guide to its path or direction, and to restrain the splitting in favour of the cutting action."

"It is well known that most pieces of wood will plane better from one end than from the other, and that when such pieces are turned over they must be changed end for end likewise. The necessity for this will immediately appear if we remember the fibres of which the wood is composed. It rarely happens that the fibres will be exactly parallel to the face of the work; the plane, then, when working with the grain, would cut smoothly, as it would rather press down the fibres than otherwise, whereas when the plane is used in the other direction it will meet the fibres cropping out, and be liable to tear them up."

"The handsome characters of showy woods greatly depend upon all kinds of irregularities in the fibres, so that the direction in which the plane should be applied is continually changing. Even the most experienced workman will apply the smoothing-plane at various angles across the different parts of such wood according to his judgment. In extreme cases, when the wood is very knotty, the plane can scarcely be used at all, and such pieces are finished with the steel scraper."

PRINCIPLES OF DESIGN.—VIII.

By Christopher Dresser, Ph.D., F.L.S., etc.

SOME GENERAL ART PRINCIPLES.

I INTENDED devoting this chapter to the consideration of furniture, and of the art principles which are involved in its formation; but I feel that there are principles which have not yet been considered that are so important, and of such general application, that I cannot pass to consider any one art manufacture till these have been considered.

The first principle to which I must ask your attention is *utility*, for the first aim of the designer of any article must be to render the object which he produces useful. I may go further to say, that an article must be made not only useful, but as perfectly suited to the purpose for which it is intended as it can be. It matters not how beautiful the object is intended to be; it must first be formed as though it were a mere work of utility, and, after it has been carefully created with this end in view, it may then be rendered as beautiful as you please.

There are special reasons why our works should be useful as well as beautiful, for if an object, however beautiful it may be in shape, however richly covered with beautiful ornaments, or however harmoniously coloured, be unsuitable for use, it will ultimately be set aside, and that which is more convenient for use will replace it, even if the latter be without beauty. As an illustration of this fact, let us suppose the balustrade railings of a staircase very beautiful, and yet furnished with such projections as render it almost impossible that we walk up or down the stairs without tearing our dress, or injuring the person, and how soon will our admiration of the beautiful railing disappear, and even be replaced by hatred! In like manner let the handle of a door, or the head of a poker, be so formed as to hurt the hand, and the simple round knob, or round head, will be preferred to it, however ornamentally or beautifully formed it may be.

In relation to this subject, Professor George Wilson has said: "The conviction seems ineradicable from some minds, that a beautiful thing cannot be a useful thing, and that the more you increase the beauty of the necessary furniture or the implements of every-day life the more you lessen their utility. Make the Queen's sceptre as beautiful as you please, but don't try to beautify a poker, especially in cold weather. My lady's vinaigrette carve and gild as you will, but leave untouched my pewter inkbottle. Put fine furniture, if you choose, into my drawing-room; but I am a plain man, and like useful things in my parlour, and so on. Good folks of this sort seem to labour

under the impression that the secret desire of art is to rob them of all comfort. Its unconfessed but actual aim, they believe, is to realise the faith of their childhood, when it was understood that a monarch always wore his crown, held an orb in one hand and a sceptre in the other, and a literal interpretation was put upon Shakespeare's words,

"'Uneasy lies the head that wears a crown!'

Were art to prosper, farewell to fire-proof, shapeless slippers, which bask like salamanders unharmed in the hottest blaze. An æsthetic pair, modelled upon Cinderella's foot, and covered with snow-white embroidery, must take their place, and dispense chilblains and frost-bite to miserable toes. Farewell to shooting-coats out a little at the elbows, to patched dressing-gowns, and hair-cloth sofas. Nothing but full dress, varnished boots, spider-legged chairs, white satin chair-covers, alabaster ink-bottles, velvet door-mats, and scrapers of silver or gold. It is astonishing how many people think that a thing cannot be comfortable if it is beautiful. . . . If there be one truth which the Author of all has taught us in his works more clearly than another, it is the perfect compatibility of the highest utility with the greatest beauty. I offer you one example. All are familiar with the beautiful shell of the nautilus. Give the nautilus itself to a mathematician, and he will show you that one secret of its gracefulness lies in its following in its volute or whorl a particular geometrical curve with rigid precision. Pass it from the mathematician to the natural philosopher, and he will show you how the simple superposition of a great number of very thin transparent plates, and the close approximation of a multitude of very fine engraved lines, are the cause of its exquisite pearly lustre. Pass it from the natural philosopher to the engineer, and he will show you that this fairy shell is a most perfect practical machine, at once a sailing vessel and a diving-bell, in which its living possessor had, centuries before Archimedes, applied to utilitarian ends the law of specific gravity, and centuries before Halley had dived in his bell to the bottom of the sea. Pass it from the engineer to the anatomist, and he will show you how, without marring its beauty, it is occupied during its lifetime with a most orderly system of rowing and sailing tackle, chambers for food, pumps to keep blood circulating, ventilating apparatus, and hands to control all, so that it is a model ship with a model mariner on board. Pass it lastly from the anatomist to the chemist, and he will show you that every part of the shell and the creature is compounded of elements, the relative weights of which follow in each individual nautilus the same numerically identical ratio.

"Such is the nautilus, a thing so graceful, that when we look at it, we are content to say with Keats—

"'A thing of beauty is a joy for ever;'

and yet a thing so thoroughly utilitarian, and fulfilling with the utmost perfection the purely practical aim of its construction, that our shipbuilders would be only too thankful if, though sacrificing all beauty, they could make their vessels fulfil their business ends half so well."

Viewing our subject in another light, and with special reference to architecture, we notice that unless a building is fitted for the purpose intended, or, in other words, answers utilitarian ends, it cannot be esteemed as it otherwise might be, even though it be of great æsthetic beauty. In respect to this subject, Mr. Owen Jones has said, "The nave and aisles of a Gothic church become absurd when filled with pews for Protestant worship, where all are required to see and hear. The columns of the nave which impede sight and sound, the aisles for processions which no longer exist, rood-screens, and deep chancels for the concealment of mysteries, now no longer such, are all so many useless reproductions which must be thrown aside." Further, "As architecture, so all works of the decorative arts, *should possess fitness*, proportion, harmony; the result of all which is repose." Sir Digby Wyatt has said, "Infinite variety and unerring fitness govern all forms in Nature." Vitruvius: "The perfection of all works depends on their fitness to answer the end proposed, and on principles resulting from a consideration of Nature itself." Sir Charles L. Eastlake: "In every case in Nature where fitness or utility can be traced, the characteristic quality, or *relative* beauty, is found to be identical with that of fitness." A. W. Pugin: "How many objects of ordinary use are rendered monstrous and ridiculous simply because the artist, instead of seeking the most convenient form, and then decorating it, has embodied some extravagance to conceal the real purpose for which the article has been made." And with the view of pointing out how fitness for, or adaptation to the end proposed is manifested in the structure and disposition upon the earth of plants, I have written in a little work now out of print: "The trees which grow highest upon the mountains, and the plants which grow upon the unsheltered plain, have usually long, narrow, and rigid leaves, which, owing to their form, are enabled to bear the fury of the tempest, to which they are exposed, without injury. This is seen in the case of the species of fir which grow at great altitudes, where the leaves are more like needles than leaves as they commonly occur; and also in the species of heath which grow upon exposed moors: in both cases the plants are, owing to the form of the leaf, enabled to defy the blast, while those with broad leaves would be shattered and destroyed.

"Not only is the form of leaf such as fits these plants to dwell in such inhospitable regions, but other circumstances also tend to this result. The stems are in both cases woody and flexible, so that while they bend to the wind they resist its destroying influence by their strength and elasticity. In relation to the stem of the papyrus," which is a plant constantly met with in Egyptian ornaments, "Sir W. J. Hooker mentions an interesting fact which manifests adaptation to its position. This plant grows in water, and attaches itself to the margins of rivers and streams, by sending forth roots and evolving long underground stems in the alluvium of the sides of the waters. Owing to its position it is exposed to the influences of the current which it has to withstand, and this it does, not only by having its stems of a triangular form—a shape well adapted for withstanding pressure—but also by having them so placed in relation to the direction of the stream, that one angle always meets the current, and thus separates the waters as does the bow of a modern steam-ship."

I might multiply illustrations of this principle of *fitness*, or *adaptation to purpose*, as manifested in plants, to an almost indefinite extent; but when all had been said, we should yet have but the simple truth before us, that the primary object which we should have in creating any object, is that of rendering it perfectly fitted to answer the proposed end. If those works which are beautiful were but invariably useful, as they should be; if those objects which are most beautiful were also the most convenient and useful—and there is no reason why they should not be so—how the beautiful would become loved and sought after. Cost would be of little moment, the price would not be complained of, if beautiful objects were works of perfect utility. But, alas! it is far otherwise: that which is useful is often ugly, and that which is beautiful is often inconvenient to use. This very fact has given rise to the highly absurd fashion of having a second poker in a drawing-room set of fire-irons. The one poker is ornamental, possibly, but it is to be looked at; the other is for use, and as it is not to be looked at is hidden away in some corner, or close within the fender. I do not wonder at the second poker being required; for nineteen out of every twenty pokers of an ornamental (?) character which I have seen during the last few years would hurt the hand so insufferably if they were used to break a lump of coal with, that it would almost be impossible to employ them constantly for such a purpose. But why not abolish the detestable thing altogether? If the poker is to be retained as an ornament, place it on the table or chimney-piece of your drawing-room, and not down on the hearth, where it is at such a distance from the eye that its beauties cannot be discovered. It is no use saying it would be out of place in such a position. If to poke the fire with, its place is within the fender, if it is an ornament, it should be placed where it can be best seen—in a glass case, if worthy of protection.

I hope that sufficient has now been said upon this all-important necessity, that if an object is to be beautiful it should also be useful, to cause us to consider it as a primary principle of design that all objects which we create *must* be useful. To this as a first law we shall constantly have to refer. When we construct a chair we shall ask, is it useful? is it strong? is it properly put together? could it be stronger without using more or a stronger material? and then we should consider whether it

is beautiful. When we design a bottle we shall inquire, is it useful? is it all that a bottle should be? could it be more useful? and then, is it beautiful? When we create a gas-branch we shall ask, does it fulfil all requirements, and perfectly answer the end for which it is intended? and then, is it beautiful? And in relation to patterns merely, we shall also have to make similar inquiries. Thus, if drawing a carpet design, we shall inquire, is this form of ornament suitable to a woven fabric? is it suitable to the particular fabric for which it is intended? is the particular treatment of the ornament which we have adopted the best possible when we bear in mind that the carpet has to be walked over, is to act in relation to our furniture as a background does to a picture, and is to be viewed at some distance from the eye? and then, is it beautiful? Such inquiries we shall put respecting any object the formation of which we may suggest: hence, in all our inquiries, I shall, as I love art, consider utility before beauty, in order that my art may be fostered and not despised.

There are many subjects not yet named in these chapters which we ought to consider, but I must content myself by merely mentioning them, and you must be willing to think of them, and consider them with care as their importance may demand. Some of them, however, we shall refer to when considering the various manufactures.

A principle of great importance in respect to design is, that *the material of which an object is formed should be used in a manner consistent with its own nature, and in that particular way in which it can be most easily worked.*

Another principle of equal importance with that just set forth, is this: that *when an object is about to be formed, that material (or those materials) which is most appropriate to its formation should be sought and employed.* These two propositions are of very great importance, and the principles which they set forth should never be lost sight of by the designer. They strike at the very root of successful designing, for if ignored the work produced cannot be satisfactory.

Curves will be found to be beautiful just as they are subtle in character; those which are most subtle in character being most beautiful.

The arc is the least beautiful of curves (I do not here speak of a circle, but of the line, as a line, which bounds the circle); being struck from one centre, its origin is instantly detected; while the mind requires that a line, the contemplation of which shall be pleasurable, must be in advance of its knowledge, and call into activity its powers of inquiry. The elliptic curve, or curve bounding the ellipse, is more beautiful than the arc, for its origin is not so strikingly apparent, being formed around two centres. The curve of the egg is more beautiful still, being formed around three centres. As the number of centres necessary to the formation of a curve increases, the difficulty of detecting its origin also increases, and the variety which the curve presents is also proportionally great; the variety being obviously greater as the number of the centres from which it is struck is increased.

Proportion, like the curve, must be of a subtle nature.

A surface must never be divided for the purpose of decoration into halves. The proportion of 1 to 1 is bad. As proportion increases in subtlety it also increases in beauty. The proportion of 2 to 1 is little better; the proportion of 3 to 8, or of 5 to 8, or of 5 to 13, is, however, good, the last named being the best of those which I have adduced; for the pleasure derived from the contemplation of proportion increases with the difficulty of detecting it. This principle is true in relation to the division of a mass into primary segments, and of primary segments into secondary forms, as well as in relation to grouping together parts of various sizes; hence it is worthy of special note.

A principle of order must prevail in every ornamental composition.

Confusion is the result of accident, order of thought and care. The operation of mind cannot well be set forth in the absence of this principle; at least, the presence of a principle of order renders the operation of mind at once manifest.

The repetition of parts frequently aids in the production of ornamental effects.

The kaleidoscope affords a wonderful example of what repetition will do. The mere fragments of glass which we view in this instrument would altogether fail to please were they not repeated with regularity. Of themselves repetition and order can do much.

Alternation is a principle of primary importance in certain ornamental compositions.

In the case of a flower (as the buttercup, or chickweed, for example), the coloured leaves do not fall over the green leaves (the petals do not fall over the sepals), but between them—they alternate with them. This principle is not only manifested in plants, but also in many ornaments produced in the best periods of art.

If plants are employed as ornaments they must not be treated imitatively, but must be conventionally treated, or rendered into ornaments.

A monkey can imitate, man can create.

These are the chief principles which we shall have to notice, as involved in the production of ornamental designs.

The next paper will be devoted to the consideration of art furniture, but in it we shall have to discuss questions involved in the construction of all art objects.

TECHNICAL DRAWING.—XVIII.

DRAWING FOR MACHINISTS AND ENGINEERS.

PRACTICAL GEOMETRY (*continued*).

FIG. 194.—*To draw a curve which shall be a portion of a circle, when the centre is not available.*

Let A B be the *chord* of the arc, and D C its *rise.*

From A and B as centres, with the radius A B, describe the arcs A E and B F.

From A draw a line through C, cutting the arc B F in G.

From B draw a line through C, cutting the arc A E in H.

Divide A H and B G into any number of equal parts, as, 1, 2, 3, 4, 5, and set off a number of these parts from G and H, as *a*, *b*, *c*, *d*, *e*.

Draw lines from A to 1, 2, 3, 4, 5, and from B to *a*, *b*, *c*, *d*, *e*.

Then it will be seen that the first line above H—viz., *a*—intersects the first line below G—viz., 1—in the point X.

In the same manner line 2 will intersect *b*, line 3 will intersect *c*, and lines 4 and 5 will cut *d* and *e*

Proceed in the same manner on the opposite side, and through the intersections trace the curve by hand.

For inking, a "templet" may be made; and as this plan will be recommended in several other cases, the mode of making this useful article is given.

Draw the figure accurately on a smooth piece of veneer of other thin wood; if of a light colour, so much the better; or a small quantity of veneer may be kept by you, with thin white paper glued over it.

Cut out the form *near* to the line required, and bring it exactly up to the mark by means of a fine file: a half-round file is best for this, as it enables you to finish up concave as well as convex curves. The final smoothing is then to be done with very fine glass-paper, and in this process the edges should be slightly bevelled off (as already advised in the case of set-squares), in order to prevent the ink dragging on the paper.

Sets of curves of different radii and "French curves" of various forms may be purchased, and though these will be found very useful in their way, the above hints are given, as it is deemed advisable to promote self-help as much as possible.

The student will remember that no portion of a true ellipse is a part of a circle, and the curve cannot, therefore, be drawn with compasses so as to be mathematically correct; but there are many ways in which figures nearly approximating to ellipses may be drawn by arcs of circles, which are very useful for general practical purposes. In mechanical drawing, therefore, figures approximating to ellipses are used, and have the advantage that they can be drawn by means of compasses instead of by hand. The following method is given in addition to those which will be found in "Practical Geometry applied to Linear Drawing."

To construct an elliptical figure by means of arcs of circles (Fig. 195).

Place the two diameters A B and C D at right angles, and intersecting each other at their middle point, E.

From B on the line A B set off B F equal to E C. From E on E C set off E G equal to E F. Draw G F, and bisect it in I. From F set off F J equal to F I. Draw J K parallel to G F. From E set off E L and E M equal to E J.

Complete the square J K L M, and produce the sides beyond J and L. The angles of the square are the centres from which the elliptical figure may be drawn.

From K and M, with radius K D or M C, describe arcs cutting the produced sides of the square in N, O and P, Q.

From J and L, with radius L A or J B, describe arcs joining N P and O Q, which will complete the figure.

Fig. 196.—*To bisect the space contained between two lines,* A *and* B, *inclined to each other when the point at which they would meet is inaccessible.*

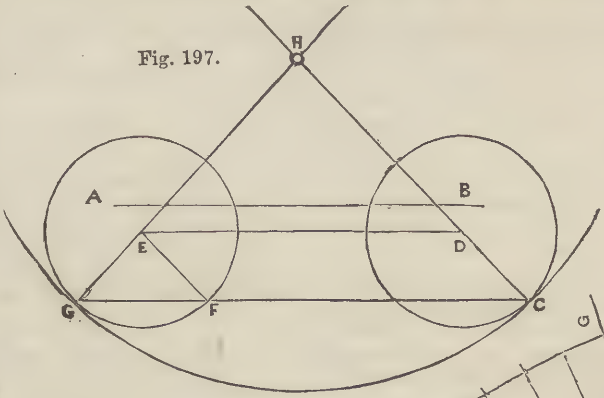

Fig. 197.

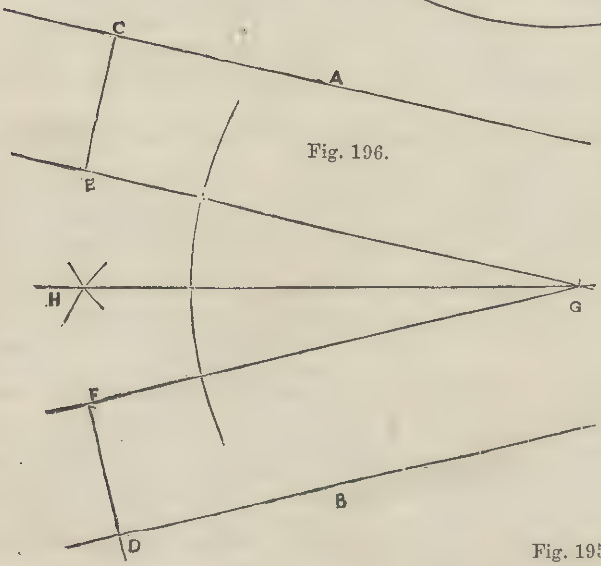

Fig. 196.

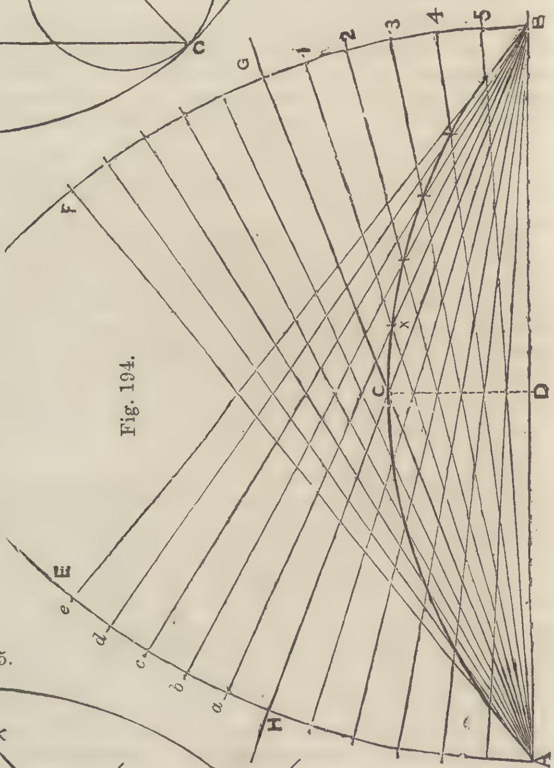

Fig. 194.

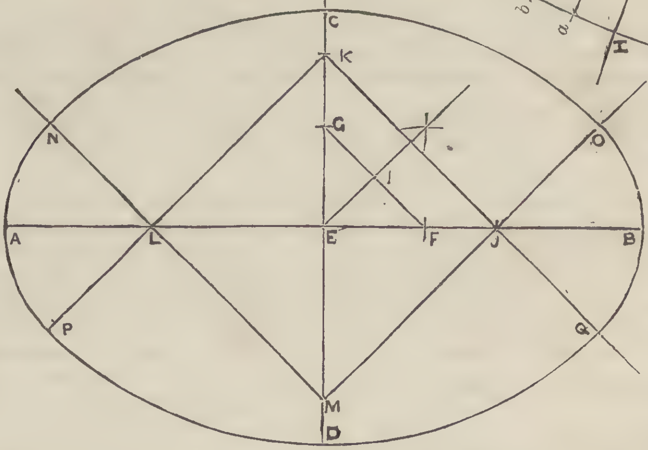

Fig. 195.

At any part of each line erect equal perpendiculars, as C E and D F, and from their extremities draw lines parallel to A and B, intersecting in G.

Bisect the angle E G F, and the line G H will bisect the space contained between the lines A and B.

Fig. 197.—*To describe a circle touching two given circles,* A *and* B, *and one of them in a given point of contact,* C.

Join the centres D and E.

Draw a line from C, passing through D, and produce it.

At E draw E F parallel to D C.

Draw C F parallel to E D, and produce it to G.

Draw G E, and produce it until it intersects C D produced in H.

From H, with radius H C, describe the required circle, which will touch both the circles A and B, and one of them in the given point C.

Fig. 198.—*To divide a circle into any number of equal parts.*

The following constructions, which require the compasses alone, are best made with the steel dividers, and if two or three pairs can be employed, the distances (such as the radius of the circle), often required, can be kept unaltered.

With the given radius describe the circle, and divide it into *six* parts in B, C, D, E, F, G. B E is a diameter, and therefore divides it into *two*. B D is the chord of $\frac{2}{6}$ or $\frac{1}{3}$, and the circle is divided in B, D, F into *three* parts.

From each end of the diameter B E, with the chord of B D or C E, describe arcs intersecting in X.* Then the distance A X being set off from B and E, the circumference will be divided into *four* parts in H, B, I, E.

The arc described with the radius A B from X, X as centres will cut the circumference in K, L, M, and N, which points bisect the quadrants B H, H E, E I, and I B, and thus divide the circle into *eight* equal parts.

The radius A B, set off from H, I to O, P, Q, R, bisects the arcs

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* In all these constructions, in order to ensure greater accuracy, the arcs should be described on both sides of the line joining the centres; thus the point X should be found on both sides of the diameter B E.

B C, D E, E F, and G B, which completes the trisection of each quadrant, and therefore divides the circle into *twelve* parts.

The radius A B, set off from K, L, M, and N, both ways from each point, will bisect the two arcs on each side of the extremities of the diameters, B E, I H in S, Y, U, V, W, Z, *a*, *b*, and thus complete the division of the circle into *twenty-four* parts.

Any further subdivision may either be done by bisecting the arcs already formed, or by trial. Thus each of the twenty-four parts being bisected, the circle will be divided into *forty-eight* parts.

All the foregoing constructions, by which the circumference is divided into twenty-four parts, are performed, it will be seen, *by three distances only*, the radius A B, the chord B D, and A X; consequently, if these be kept unaltered in separate pairs of dividers, the operations are performed with the greatest accuracy.

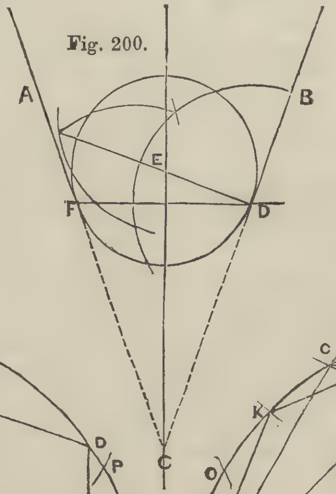


Fig. 200.

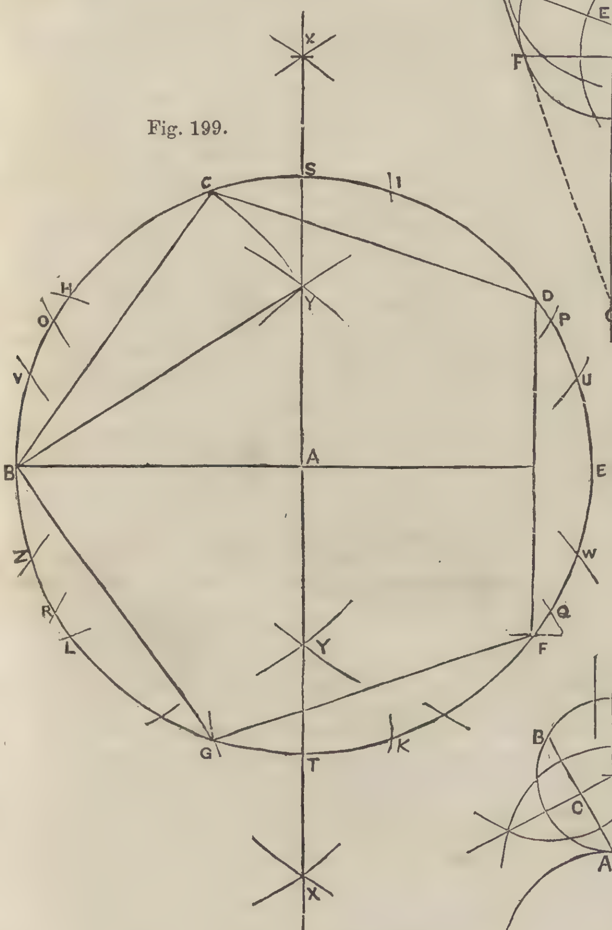


Fig. 199.

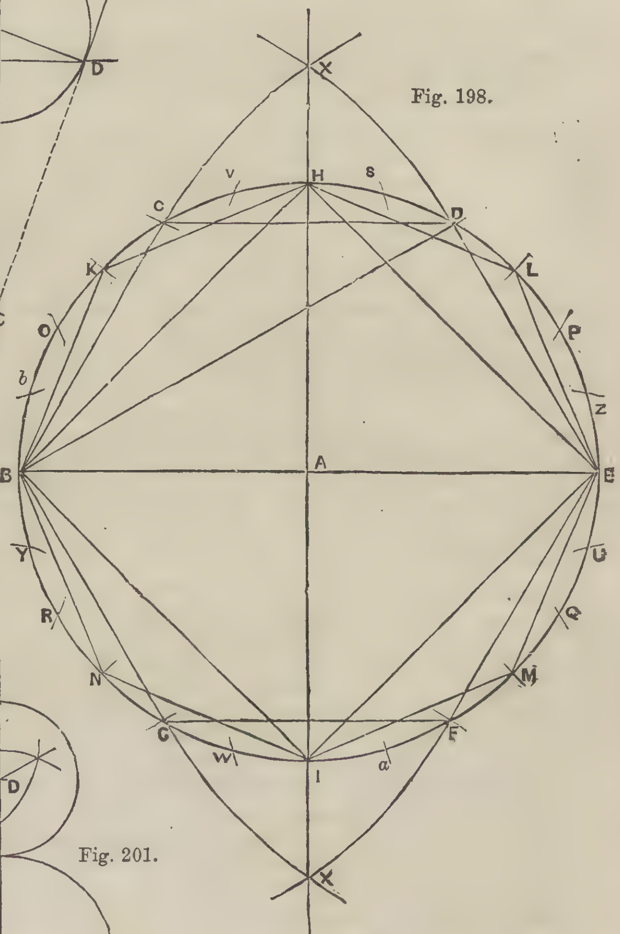


Fig. 198.

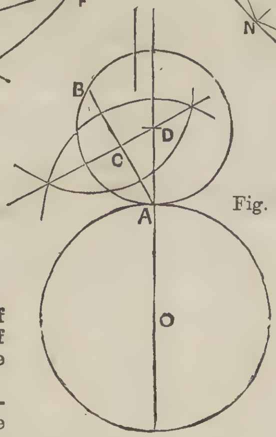


Fig. 201.

In order to avoid confusion, the continuation of this problem is given in a separate figure (Fig. 199). With the distance A X as a radius, from O, P, Q, R (these points having been found as in the last figure), describe arcs intersecting in Y; then the distance B Y, or E Y, will divide the circumference into *five* equal parts in B, C, D, F, and G. The distance A Y will bisect the arcs B C, C D, D F, etc., in H, I, E, K, L, and thus divide the circle into *ten* parts.

The distance B Y, set off from S, T, the extremities of the diameter S T, perpendicular to B E, will bisect the arcs D E, B H, E F, B L in the points U, V, W, Z, and will thus give *one-twentieth* of the circumference. The same distance being set off from these points will bisect the other arcs of the decagon.

The division into *forty* parts may be effected by bisecting the arcs last found.

These constructions will be found useful in drawing regular polygons, and in dividing the circles for toothed wheels. Of course no more of the figure need be worked than is necessary for the immediate purpose.

Fig. 200.—*To join two lines,* A B, *inclined to each other, by an arc of a circle.*

Produce A and B until they meet in C.

Bisect the angle A C B.

At D, the extremity of one of the lines, erect a perpendicular, cutting the line of bisection in E. From E, with radius E D, describe the arc D F which will meet A in F.

If the point C is not accessible, the angle must be bisected as shown in Fig. 196 in the preceding page. This method of bisecting an angle should be carefully practised by the learner.

Fig. 201.—*To draw a circle touching another circle in a given point, and passing through a given point lying without the circle.*

Let A be the point of contact in the given circle, and B the point lying without it.

The centre of the required circle will evidently lie on the radius O A produced, and on a perpendicular at the middle of a line joining A B, which line will be a chord of the required circle; therefore

Produce O A to as great a length as may be necessary.

Draw a line from A to B, and bisect it in C.

Produce the bisecting line until it cuts O A produced in D. The point D is the centre of the required circle, D A being the radius.

PROJECTION.—XII.

QUESTIONS FOR EXAMINATION.

The following questions, selected for the most part from the papers given at the Government and other examinations, are appended with the view of enabling the student to test his own knowledge, and as suggestions to teachers as to the mode of stating problems on this subject. It is hoped that the examples already given, and the application of them, will have shown the constructions upon which all the questions are based.

1. Give the plan and elevation of a line 3 inches long, when parallel to the vertical and horizontal plane, and 2 inches distant from each.

2. Give the plan and elevation of this line when it is at right angles to the vertical and parallel to the horizontal plane, its height being 2 inches from the ground.

3. Give the plan and elevation of the same line, when the former is a point, and the latter a vertical line 3 inches long.

4. Give the elevation and plan of the same line when it is parallel to the vertical, but is inclined to the horizontal plane at 70°.

5. Give the plan and elevation of the line, when it is inclined at 70° to the horizontal, and 45° to the vertical plane.

6. A wire 3 inches long projects from a wall at 60° to the surface, and is parallel to the ground. Give the plan and elevation.

7. A plane 2″ × 3″ rests on its narrow edge in such a manner that its surface is at right angles to both planes. Give plan and elevation.

8. Give plan and elevation of the same plane, when its surface is vertical, but inclined to the vertical plane at 45°.

9. Give plan and elevation of the same plane when its shorter edges are at right angles to the vertical plane, and its surface inclined to the horizontal plane at 60°.

10. Give plan and elevation when the plane rests on one of its short edges, its surface being inclined at 60° to the horizontal plane, and its long edges being at 45° to the vertical plane.

11. A square plane of 3 inches side lies on the horizontal plane, its one diagonal being at right angles to the vertical plane, and the other parallel to it. Give plan and elevation.

12. Give elevation and plan when the plane rests on one of its angles, its surface being inclined at 40° to the horizontal plane, but its one diagonal remaining at 90° to the vertical plane.

13. Give plan and elevation of the same plane when one of its diagonals is at 45° to the horizontal, and 60° to the vertical plane, the other diagonal being parallel to the horizontal plane.

14. A cube of 2 inches side stands on the horizontal plane, with two of its faces parallel to the vertical plane. Give its plan and elevation.

15. Draw its plan and elevation when standing on one of its sides, the opposite one being horizontal, and the others being at 45° to the vertical plane.

16. Give plan and elevation when resting on one of its solid angles, one diagonal of the base being at 50° to the horizontal, and the other at 90° to the vertical plane.

17. Draw elevation and plan of the same cube, when resting on one of its *edges*, so that two of its sides are vertical and the rest make angles of 45° with the horizontal, but are at right angles to the vertical plane.

18. Add the shape (the *development*) of the piece of metal or other substance which on being folded would form the above-named cube.

19. There is a stick of timber 2 inches square at base, and 5 inches high. Give the true shape of a section caused by a plane entering at one angle of the top, and emerging at the opposite angle of the base.

20. Give the development of one portion of this square prism when it has been cut as in the last question.

21. Give plan and elevation of a triangular prism when resting on one of its long faces, the surface of the triangular end being at 50° to the vertical plane. The end is an equilateral triangle of 2 inch edge, and the length of the prism is 3½ inches.

22. Give plan and elevation of the same prism when the edge of the end on which it rests is at 50° to the vertical plane, and the under side is inclined to the horizontal plane at 35°.

23. Add the development of this prism.

24. Draw the plan and elevation of a regular pentagon of 1 inch side when resting on one of its angles, so that its surface is at right angles to the vertical, and at 60° to the horizontal plane.

25. Give the projection of this polygon when the line joining the angle on which it rests to the middle of the opposite side is at 40° to the vertical plane, the inclination to the horizontal plane remaining the same as in the last figure.

26. There is a hexagonal prism of 1 inch side and 4 inches long. Draw plan and elevation when standing on its end, with two of its faces parallel to the vertical plane.

27. Give the plan and elevation of the same prism, when the axis is vertical and one of its faces is at 40° to the vertical plane.

28. Give elevation and plan of the same prism when two of its faces are parallel to the vertical plane, and the prism is so inclined that the axis is at 50° to the horizontal plane.

29. Draw the plan and elevation when the prism rests on one of the solid angles, and the axis is at 50° to the horizontal, and 45° to the vertical plane.

30. Project the prism when lying on one of its long faces, the axis being at 40° to the vertical plane.

31. Give the true section caused by a plane passing from one angle of the top to the opposite angle of the bottom.

32. Draw the development of the prism, marking on it the line of section, as per last figure.

33. There is a prism, the ends of which are regular octagons of ¾ inch side, and the sides of which are 4 inches long. Give the plan and elevation of this object when the one edge of the base rests on the ground, and the corresponding edge of the top touches the edge of a cube of 2 inches side.

34. Give the plan and elevation of this group when rotated so that the sides of the cube are at 45° to the vertical plane.

35. Project the front view of an octagonal prism (size at pleasure), when its end rests in a plane inclined at 35°, neither of the long faces being parallel to the vertical plane.

36. Give a section of the prism named in Question 33, caused by a plane passing through it at 60° to the axis; the prism to be hollow, and formed of wood ⅛ inch thick.

37. Give plan and elevation of a hexagonal pyramid when two of the edges of the base (1 inch long) are at 20° to the vertical plane, the altitude being 2½ inches.

38. Draw elevation and plan of this pyramid when lying on one of its triangular faces, with its axis parallel to the vertical plane.

39. Give the elevation and plan of this pyramid when resting on one angle of the base, and one of its edges being vertical.

40. A circular disc (1½ radius) stands so that one diameter is vertical, and another at right angles to the first is at 50° to the vertical plane. Give plan and elevation.

41. Give elevation and plan of the same circular disc, when resting on the end of one diameter, which is parallel to the vertical plane, the surface being at 40° to the horizontal plane.

42. Draw the plan and elevation of the same disc, when the diameter is at 40° to the horizontal and 60° to the vertical plane.

43. A circular slab of stone, such as a mill-stone, 4 feet diameter and 1 foot high (*to be represented by inches for feet*), lies on the horizontal plane. Give the plan and elevation.

44. A second circular slab, 3 feet diameter, and 1 foot high, rests on a slab, similar to the last; their centres being coincident. Draw the plan and elevation.

45. Draw the elevation, plan, and projection of these two slabs, one placed on the other, as above, when their circular surfaces are inclined at 40° to the horizontal plane.

46. A cylinder, 4 inches long and 2 inches diameter, stands on its circular end. Give the plan and elevation.

47. Draw the plan and elevation of the same cylinder when lying on the horizontal plane, its axis being parallel to both planes of projection.

48. Give plan and elevation of the cylinder when lying on the horizontal plane, its axis being at 60° to the vertical plane.

49. Draw the plan and elevation of a cylinder 4 inches long and 2 inches diameter, when the axis is inclined at 60° to the horizontal and 45° to the vertical plane.

50. Give the true section caused by a plane passing through the middle point of the axis at 45° to it.

51. Draw the development of this cylinder, marking on it the line of section.

52. A cylindrical pipe, of 2 inches diameter, is to be cut so as to turn a right angle. Give plan and elevation, showing the section-line.

53. Give the elevation and plan of one of the parts when resting on the sectional surface.

54. Give the true shape of the section, and the development, showing how both parts of the elbow may be cut out of the same piece of metal without any waste.

55. From piping of the same diameter, construct a double elbow-joint, one end of which bends one way and the other the opposite. Give development of the three parts to be cut out of one piece without waste.

56. The same piping is to be carried round three sides of a square room (size at pleasure). Give development, showing the section-line.

57. A pipe of sheet iron (2 inches diameter) is to be joined so as to turn an angle of 120°. Show on an elevation the inclination of the line of section, and show on a development the line in which the metal must be cut to form the required parts without any waste.

58. Given a cone of $2\frac{1}{2}$ inches base and $3\frac{1}{2}$ inches altitude. Draw the plan and elevation of this cone when standing on its base.

59. Give elevation and plan, when the cone lies on the horizontal plane, its axis being parallel to the vertical plane.

60. Draw the projection of the cone, when lying on the horizontal, with its axis at 45° to the vertical plane.

61. Project the cone when resting on one end of the diameter of the base, the axis being inclined at 70° to the horizontal plane.

62. Project the cone, when the axis is inclined at 70° to the horizontal and 45° to the vertical plane.

63. Draw the true section of the same cone caused by a plane at 40° to the surface of the base, which enters at $\frac{1}{4}$ inch from the bottom.

64. Draw the parabola resulting from a plane entering the base of a similar cone at $\frac{3}{4}$ inch from the centre.

65. Draw the hyperbola resulting from a section-plane entering the base of a similar cone at $\frac{3}{4}$ inch from the axis.

66. A pipe 2 inches square is penetrated by another of 1 inch side. The smaller one passes through 2 sides of the larger, their axes being at right angles to each other. Give elevation and plan when two faces of each of the pipes are parallel to the vertical plane.

67. Project this object when the two faces, which in the last case were parallel to the vertical plane, are at 60° to it.

68. Give the development of the larger pipe, showing the exact shape of the aperture through which the smaller one is to pass.

69. Give the elevation and plan of the object when the smaller pipe penetrates the sides of the larger at 60°.

70. Draw the development of the larger pipe, showing the apertures, and of one piece of the smaller one.

71. A square pipe of 2 inches side is penetrated by another of $1\frac{1}{2}$ inch side, their axes being at 60° to each other, and parallel to the vertical plane; and two *edges* of the smaller meeting two edges of the larger pipe. Give the elevation and plan.

72. Draw the plan and elevation, when two faces of the larger pipe are parallel to the vertical plane.

73. Draw the development of the larger pipe, showing the shape of the apertures through which the smaller one is to pass, and also one of the ends of the smaller pipe.

74. A cube of 3 inches side stands on the horizontal plane, and is surmounted by a square pyramid, 3 inches high. Give elevation and plan, when two faces of the cube and two of the sides of the base of the pyramid are parallel to the vertical plane.

75. Draw the elevation and plan of this object, when the faces are parallel to the vertical plane, as in the last question, but when the base is inclined at 25° to the horizontal plane.

76. Draw the plan and elevation of the object, when the sides of the cube are at 50° and 40° to the vertical plane.

77. Give plan and elevation of the object, when the faces of the cube are at 45°, and two of the sides of the base of the pyramid are parallel to the vertical plane, their axes being coincident.

78. Draw the shape of the piece of metal to form a gas-shade, 20 inches wide across the circular base, 6 inches across the top, and 10 inches perpendicular height. (To be worked $\frac{1}{2}$ size.)

79. A cylindrical coal-scuttle is to be made of sheet iron; it is to be 10 inches in diameter and 18 inches high at the highest part, the lid to be inclined at 45°. Draw the shape the metal is to be cut to form this object, and the exact shape of the lid. (To be worked $\frac{1}{4}$ size.)

80. A cylinder, $2\frac{1}{2}$ inches diameter and 6 inches long, is penetrated by another of $1\frac{1}{2}$ inch diameter and 5 inches long, their axes being at right angles to each other, and intersecting at their centres. Show the mode of obtaining the curves of penetration. Develop the larger cylinder and one of the ends of the smaller one.

81. Draw the plan and elevation of this object when the axis of the larger is parallel, and of the smaller at 60° to the vertical plane.

THE STEAM-ENGINE.—IV.

By J. M. Wigner, B.A.

BOILERS (*concluded*)—THE FURNACE—RELATIVE VALUE OF DIFFERENT KINDS OF COAL—DRAUGHT—SMOKE-CONSUMING ARRANGEMENTS—TEMPERATURE AND PRESSURE.

We have now referred to those forms of boiler which have come into most general use. There are, however, many other varieties, some of which are only available for special and peculiar work, while others are of comparatively recent introduction, and have as yet to stand the test of experience. Sectional wrought-iron boilers have been tried of late years, with apparently good results. In these the water is contained in wrought-iron tubes of comparatively small diameter, round which the flame and heated gases are made to play. These tubes are proved to a great pressure before being used, and are so arranged that if by accident any one should become injured or ruptured it can easily be either cut out of communication with the rest of the boiler, or removed and replaced by a fresh one. In one form of boiler, on this principle, a number of parallel wrought-iron tubes are placed above the furnace, from each of which a small tube leads into the general steam-pipe. In other forms, the tubes are connected to one another at the ends, but the connections are so arranged that any defective one can easily be separated from the rest. Many advantages are claimed by the manufacturers of these boilers, among which are economy in use and greatly-increased safety—an injury being easily discovered and repaired, and an explosion of the whole being rendered almost impossible.

One of the uses to which the steam-engine has been applied is to work a fire-engine. In large towns, where dwellings and warehouses are closely packed, fires spread very rapidly, and manual engines are found not to be sufficiently powerful to extinguish them with promptitude. Steam is therefore employed; but in this case the desideratum is an engine and boiler so constructed as to get up steam in a very short time, as otherwise the fire gains a very powerful hold before the engine can be set to work. Much attention has accordingly been directed to this point, and with such success that engines are now made capable of throwing very large jets of water within a few minutes of the time when their fires are lighted. The boilers usually employed are of very small dimensions, and contain a large number of short tubes very closely packed; quick-burning fuel is also employed, so that a powerful draught is at once produced. The quantity of water in the boiler is of course very small, and thus a high pressure is quickly attained. The engine is so arranged that at every stroke a small quantity of water is injected into the boiler, sufficient to take the place of that converted into steam, without materially reducing the temperature of the rest. The amount of work accomplished by these engines is very great indeed, when considered with reference to their size and weight. They are usually worked at great speed, and with steam at a pressure of from 100 to 150 pounds to the inch. In an official trial of fire-engines at the International Exhibition of 1862, steam was got up to a pressure of 100 pounds by two different engines in 12 minutes 10 seconds and $18\frac{1}{2}$ minutes respectively, from the time of lighting the fires, the boiler in each case being filled with cold water at starting. Sometimes these engines are made to propel themselves along

the road to the fire, but this plan is not generally adopted, as it is found better to start at once with horses, and get up steam while going along. One drawback to the use of boilers of this kind, with the tubes so closely placed, is that they soon become incrusted, and the fur deposited hinders the circulation of the water. As, however, fire-engines are not very often set to work, and then only for a comparatively short period, there is plenty of time for removing this accumulation, and the boiler is so constructed that the covering can easily be removed and the tubes laid bare for this purpose.

We must now pass from the details of the boiler to notice the arrangements of the furnace, many of which have already been referred to in connection with the boilers of which we have spoken.

The furnace is the source of all the power. The fuel supplied to it enters into chemical combination with the oxygen of the air, evolving thereby a large amount of heat, which, by the medium of the steam, becomes in time converted into force. The fuel usually employed is coal—a mineral substance consisting principally of carbon and hydrogen, together with some sulphur and various incombustible mineral ingredients which remain behind in the form of ash. During the process of combustion, the carbon, hydrogen, and sulphur unite with the oxygen of the air, producing various gaseous products, the principal of which are carbonic oxide, carbonic acid, and watery vapour. The exact products vary with the coal employed, different samples of which are found to differ very greatly in their composition, and accordingly in the duty they are capable of performing. Good coal ought to contain at least three-fourths its weight of carbon—often it contains considerably more.

It will easily be seen that the amount of heat produced by the consumption of a given weight of coal is a very important point in connection with the economical employment of the engine. A large number of experiments have therefore been tried with coal of every variety. A very important series of trials of this kind, conducted under Government authority at Woolwich, was brought to a close a few years ago, and the results published as a Parliamentary paper which is well worthy the attention of all employers of steam-power. These trials had extended over many years, and were carried on with great care. Boilers were fed with water at a uniform temperature of 100°: the trial was then continued some days, the exact amount of coal consumed being noted, and also the amount of water evaporated. It would be impossible here to insert even a general abstract of these trials, but the following extracts will give an idea of the average duty which should, under favourable circumstances, be obtained :—

Description of Coal.	Pounds of Water evaporated for each pound of Coal consumed.
Best Welsh Coal	9·493
Anthracite	9·014
Best Small Newcastle Coal. . .	8·524
Average Small Newcastle Coal .	8·074
Average Welsh Coal	8·045
Large Newcastle Coal	7·658
Derbyshire	6·772

Generally, then, we may state that from 7 to 9 pounds of water at 100° (which may be taken as the average temperature of feed-water) should be evaporated by each pound of coal consumed in the furnace. The best results are those obtained with a Cornish boiler, that being the form of boiler in which the greatest economy of fuel is obtained. This economy has been partly produced by the system, which has long prevailed in that district, of publishing the results obtained as compared with the coal used. This plan has produced a kind of competition that has acted very favourably. In many cases little care is taken as to the construction or management of the furnace, and the results then obtained are, of course, much inferior to those given above.

By inquiring a little into the process of combustion that goes on in the furnace we shall be able to understand more clearly the different things requisite in order to ensure perfect combustion. Carbon itself burns almost without flame when heated to a temperature of 700° or 800°. The hydrogen in the coal is for the most part combined with some of the carbon, producing the gas known as carburetted hydrogen, and this it is which produces the flame and smoke. The products of combustion are themselves invisible, but this gas carries with it small particles of the coal mechanically suspended, and, if not perfectly consumed, deposits, in addition, a portion of its carbon in the form of dark smoke.

All smoke that escapes will thus be seen to be a loss of so much fuel, and therefore, apart from the nuisance, motives of economy point to the need of fully consuming the smoke produced in any furnace.

To perfectly consume a pound of carbon requires 12 cubic feet of oxygen gas. In the air, however, this gas is diluted with four times its bulk of nitrogen; 60 cubic feet of air are therefore required to consume 1 lb. of carbon. It is not, however, to be supposed that all the oxygen is extracted from the air as it passes through the furnace: only a portion is removed, and the rest escapes up the chimney, with the products of combustion. We may, therefore, assume that about 150 cubic feet of air should pass into the furnace for each pound of coal consumed, the exact quantity varying considerably with the shape and construction of the furnace. If too little is admitted, combustion will be imperfectly carried on, and much smoke will accordingly be produced, while the heat obtained will be less than that required. On the other hand, too large a supply of cold air will materially reduce the temperature, besides carrying off a large amount of waste heat up the chimney.

The usual manner in which a powerful draught is maintained, so as to ensure a sufficient supply of air, is by means of a tall chimney.

The air having passed through the furnace becomes intensely heated, and accordingly expands. In this way it is rendered much lighter than the air around, and ascends the chimney, while fresh air rushes through the furnace to supply its place. With a stationary furnace sufficient draught can always be obtained in this way, and dampers are introduced into the flues to reduce it when needful. In locomotives, however, where a long chimney is, of course, inadmissible, artificial expedients are employed to quicken the draught.

Under ordinary circumstances, when a fresh supply of fuel is thrown into the furnace, the heat at once drives off a large portion of the carburetted hydrogen, which takes with it minute particles of dust, and the supply of air is for the time insufficient to consume these. Volumes of dense smoke accordingly issue from the chimney, and much attention has been directed to the best mode of avoiding this. Very much depends upon the manner of feeding the furnace. If a large supply of coal is thrown carelessly into it, there is sure to be a large production of smoke. If, on the other hand, the fuel be introduced in frequent small supplies, and placed near the furnace-door, the smoke produced will have to pass over the intensely-heated cinders beyond, and will be entirely consumed; and this is the principle of most of the smoke-consuming arrangements at present in use. The fuel is introduced in small quantities and at frequent intervals, and the smoke is burnt by being compelled to pass over the surface of the highly incandescent fuel already in the furnace.

Another plan by which smoke may also be reduced is by allowing an additional supply of air to enter the furnace and pass into the combustion chamber, where it mingles with the smoke, and aids in its complete combustion.

The former of these plans is by far the most generally adopted, though, of course, there are very many ways in which the principle may be carried into practice. The most important thing of all is to procure a careful and intelligent stoker, for more, as a general rule, depends on this than on the apparatus used. A perfect self-feeding apparatus would be the best preventive of smoke: this, however, has yet to be discovered.

With an ordinary furnace little smoke will be caused if the fire is well managed. The fuel, as already stated, should be introduced frequently and in small quantities. Before doing so, the stoker should open the furnace-doors and push back a portion of the fuel, so as to make a space in front for the fresh supply, which should be spread evenly on the fire-bars. It will then first become coked—that is, the gases will be expelled, and, in passing over the rest of the furnace, will be entirely consumed. The coke then burns in a clear, smokeless way.

This plan, however, requires constant care and watchfulness, which it is difficult at all times to ensure.

Some furnaces are constructed with a self-feeding arrangement. The coal employed in these is usually crushed almost to dust, or else small coal is employed. It is introduced into a hopper above the furnace, and a small revolving scoop, driven by the engine, constantly and slowly sprinkles the coal into it. A slow motion is also imparted to the furnace-bars, so that the burning fuel is gradually carried to the back of the furnace as fresh coal or coal-dust is supplied in front.

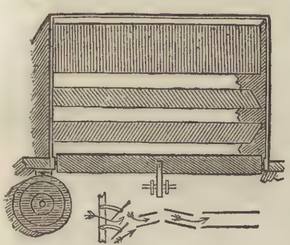


Fig. 19.

The main drawbacks to this system are the somewhat complicated nature of the mechanism and the power required to drive it, but, despite these, it is found in many places to answer very well, and to effect a saving in cost of fuel. The supply of coal is rendered quite uniform, and all the smoke is consumed. Sometimes the furnace-bars are laid transversely and connected to the links of an endless chain, and then made to travel slowly along. In other forms they are longitudinal, and an oscillating movement is given to the alternate ones at the end nearest the furnace-door, so that the same effect is produced—the coal being slowly moved back in the furnace, and the ashes discharged at the further end.

Frequently two furnaces are employed, being placed side by side, and alternately fed. These are so arranged that the smoke from the one passes through the other, and is consumed. But we cannot stay even to enumerate the different plans of smoke-consuming apparatus that have been tried. There is, however, one very ingenious and useful contrivance to which we must just refer. It is known as "Prideaux's Self-closing Furnace Valve," and serves to regulate the supply of air admitted to the furnace. The apparatus, which is fitted as a door to the furnace, consists of three series of vertical plates, placed behind one another, as shown in plan in Fig. 19. The two outer sets are a little inclined in opposite directions, so as to prevent any loss of heat by radiation. The air as it enters the furnace passes between these plates, and thus keeps the outer portion of them cool, while it becomes itself raised to a very high temperature, and thus aids more perfectly in carrying on combustion. In front of these partitions is a series of horizontal shutters, mounted so as to close somewhat after the manner of Venetian blinds (Fig. 20). A weight, *c*, fixed at the end of a lever, *a*, closes these. This weight is, however, prevented from falling rapidly by means of the cylinder, *b*, containing water. A piston works in this cylinder, and is so arranged that it can readily rise to the top, the water in the cylinder passing below it. There is, however, only a very small return channel for the water, the size of which can be regulated by a set-screw. The piston, therefore, can only fall very slowly, and as the weight *c* is connected to it, the shutters likewise close very slowly and gradually. Usually the apparatus is so adjusted that it shall take seven or eight minutes for the piston to fall.

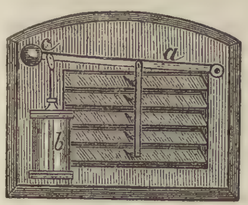


Fig. 20.

When the furnace-door is opened to introduce fresh fuel the piston is raised to the top, and the shutters are accordingly opened and admit a plentiful supply of air, which becomes heated on its way, and aids in consuming the smoke produced. As the fuel becomes coked less air is required, and the shutters gradually close, diminishing the supply. In this way the supply of air is nicely adjusted to meet the requirements of the furnace, while at the same time the air that enters is warmed, and consequently does not reduce the temperature as it otherwise would.

Other arrangements have been suggested for the purpose of warming the air by means of the waste heat, ere it is allowed to enter the furnace, but these have not been at all generally adopted.

The student will now have acquired a general acquaintance with the details of construction of the boiler and its appendages, and we can, therefore, pass on to inquire into the mechanism of the engine itself, and the different forms given to it. Before doing so, however, it will be useful to append a table, showing the temperature of steam at any given pressure. Under the ordinary pressure of the air water boils at 212°, and the temperature of the steam never exceeds this. When, however, we have a closed vessel like a boiler, and allow the pressure to become greater than that of the air, we find the temperature rises, and the ratio of this increase will at once be seen by reference to the table.

Temperature.	Pressure.		Temperature.	Pressure.	
	Atmospheres.	Pounds.		Atmospheres.	Pounds.
212°	1	15	293·7	4	60
234	$1\frac{1}{2}$	$22\frac{1}{2}$	307·5	5	75
250·5	2	30	320·4	6	90
263·8	$2\frac{1}{2}$	$37\frac{1}{2}$	358·9	10	150
285	3	45	418·5	20	300

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

VII.—JOHN SMEATON.

BY JAMES GRANT.

John Smeaton, the eminent civil engineer, constructor of the Eddystone Lighthouse and many other great works, was born in 1724 at Austhorpe, near Leeds, and from his earliest years showed an eagerness for mechanical science. Thus, in his fifteenth year he constructed a machine for rose-engine turning. He commenced business in London as a maker of mathematical instruments about the year 1750, and among various desultory experiments in mechanics, he invented a compass, and improvements in wind and water-mill machinery, an "odometer" for ships, and many other useful things. His improvements in mill-work—being found to increase the effective force of all such engines by fully one-third—were deemed of such value, that in 1759 he was awarded the Copley medal of the Royal Society.

Three years before this, he had been elected a member of the Royal Society, and in 1753 he visited Holland, and inspected the dykes, embankments, canals, and other works of note in that country, with a view to increase his knowledge of practical engineering; and soon after his return home in 1755, there occurred an event, which gave him the long-desired opportunity of rising to the summit of his profession—the destruction by fire of the old wooden lighthouse on the Eddystone Rock, off the stormy coast of Cornwall. His essay was the third erection of the kind which had been attempted there.

The Eddystone is a reef of gneiss rocks submerged daily by the tide, lying nine miles from Ram Head, and fourteen south-west of Plymouth harbour. Around them the water varies from 12 to 150 fathoms deep. They had long formed a dangerous obstacle to navigation, and many a valuable ship, after crossing the Atlantic in safety, had gone down there, in sight of land, with all its crew, even in the finest weather. The frequency of those disasters induced a wealthy and humane gentleman, named Winstanley, who had a decided turn for mechanics, to erect a lighthouse there in 1696, in the reign of William III. It was a wooden polygon, about 100 feet high, based on stone, constructed like a Chinese pagoda, and furnished with open galleries. So confident was Winstanley of its stability, that he expressed a hope to be in it "during the greatest storm that ever blew under the face of heaven;" and his wish was gratified, for in a terrific tempest, which occurred on a November night in 1703, he and all therein perished. When day dawned, not a vestige of the building remained, save an iron chain, wedged in a fissure of the rocks. Three years after this, Mr. John Rudyerd, an opulent silk-mercer on Ludgate Hill, undertook the erection of a new lighthouse, in which twenty-four candles were to burn by night. It was constructed chiefly of timber, and in December, 1755, was destroyed by fire, a spark having probably ignited some of the flakes of soot that hung from the roof above the lights.

The speedy re-erection of another beacon was of the utmost importance; but before it was undertaken, the projectors pru-

dently consulted the President of the Royal Society, who recommended Mr. John Smeaton, as the person best qualified to superintend its construction. He spent much time in considering the best methods of grafting the foundations into the rock, so as to secure stability; and in planning the present structure he took, it is said, as his model, the trunk of an oak, which so seldom succumbs to the tempest. On the 12th of June, 1757, the first stone was laid, and the night of the 16th of October, 1759, saw the saving light from its summit once more stream across the waters of the British Channel.

This great work is built on the sloping side of one of the rocks, and is formed of blocks, generally one or two tons in weight, of Portland oolite cased in granite, the latter being dovetailed solidly into the reef. To prepare a base for the tower, the shelving rock was cut into six steps, which are filled up with masonry, riveted to the living stone; and for the height of 12 feet above the base, the tower is one solid columnar mass. The interior consists of four rooms, situated one over the other, the whole being surmounted by a glass lantern and iron gallery. The base is 26¾ feet in diameter; the light, a fixed one, stands 72 feet above the water, and is visible for thirteen miles.

Such was Smeaton's greatest work, which survived without injury the memorable tempest of 1762, and is likely to endure for centuries; but with all his engineering fame, he would seem to have had little employment for some time subsequently, as in 1764 he applied for and obtained the post of "Receiver of the Derwentwater Estates," the funds of which were appropriated for the benefit of Greenwich Hospital; and this situation he held till 1777, when he was full of professional employment, and frequently consulted on the opening-up of river navigation. On this matter he reported so early as 1760 to the Provost and Bailies of Dumfries on the improvement of the shallow Nith; but his advice to form a navigable canal, rather than to deepen the sandy river, could not be carried out for want of funds. He was consulted concerning the opening-up of the Don above Doncaster, the Chelmer to Chelmsford; the lockage of the Wear, and the deepening of the Black Devon, which rises in the Saline Hills, and falls into the Forth at Clackmannan Pow; the navigation of Tetney Haven, near Louth; the improvement of the Lea; and the extensive repairs of the lockage and dams of the Calder, in Yorkshire—a subject requiring much care and consideration, owing to the floods from Blackstone Edge in rainy seasons.

The drainage of the Lincolnshire fens, and all the low-lying tract about Doncaster and Hull, were subjects on which he was frequently consulted. In reporting on this matter in 1761, he was associated with the Messrs. Grundy and Edwards, and the result of their labours was a proposal to improve the outfall by the formation of a new river, twelve miles long, from a place called Chapel-Hill to a little way above Boston; the total estimate being more than £40,000. In 1762 he suggested the improvement of the Fossdyke, an old cut that joined the Trent and the Witham; but though he was applied to on the same subject in 1782, the county was too poor to undertake the work. The greatest success attended his operations for the drainage of the isle of Axholme, by the diversion of the old river Trone; the drainage of the lands adjacent to the Went; those of Lord Kinnoul in Perthshire; at Hotham Fens; the Holderness Level, near Hull; and many other places, by which waste sheets of gloomy water—the local source of ague, fog, and fever; the haunt of wild fowl and abode of mud-fed fishes—became fertile tracts of arable land. He was consulted concerning the repair of old Bristol bridge, and in 1758 he was engaged in improving and widening the ancient bridge of London, then overhung by houses above a dark and narrow thoroughfare; and the result of his advice was the proposal to erect a new bridge at Blackfriars, the removal of the houses from the old London Bridge, the demolition of the great middle pier, and erecting there a new arch to span the space of two.

In 1763 he visited Perth, where he erected a handsome bridge, 900 feet in length, in lieu of the old one, swept away by a flood in the Tay; and now the fame of his skill brought him much engineering business in Scotland. At Edinburgh he was consulted about the supply of water for the city; at Glasgow about the security of its bridge; but his most important Scottish work was the formation of the great canal between the Forth and Clyde, a project as old as the time of Charles II. Smeaton first estimated the expense at £80,000; and after being opposed by Parliament, and having many difficulties to surmount, £150,000 were subscribed, chiefly in Glasgow, and the canal was begun under Smeaton's direction in 1768, but made navigable only as far as Stockingfield, and in that state it remained until 1784, when it was completed by sums levied on the forfeited estates. It is 37½ miles long; its medium width is 56 feet—at the bottom, 27 feet; its depth 9 feet; and it has 39 locks. It is supplied from 8 reservoirs covering 721 acres.

A bridge across the Tweed at Coldstream was Smeaton's next work. It consists of five arches founded on piles, and was opened for traffic in 1766, after costing £6,000. Two years after, he was at the Carron Iron Works, the largest of the kind in Europe, where he constructed a highly-effective machine to aid the powerful blowing-apparatus. He also supplied the company with a design for a double-boring mill for cylinders and cannon, of which vast quantities, of the form known as "carronades," were cast there until recent years. The elegant bridge of seven arches across the Deveron, near Banff, was his next work, and there, as elsewhere, he adopted the elliptical outline. He was less successful in the construction of his only English county bridge—that across the Tyne at Hexham—in 1777. A subsidence in one of the piers occurred soon after it was finished. No remedies availed; and in the spring of 1782, when a flood swept down the Tyne, "Smeaton's beautiful Hexham bridge lay a wreck in the bottom of the river." He felt this acutely, and it seemed strange that he, whose lighthouse bid defiance to the waves, was foiled by the current of an inland stream.

Harbours next occupied his attention; he constructed the pier at St. Ives in Cornwall, and was consulted concerning those at Dover, Rye, and Christchurch; Workington, Whitehaven, and Bristol; Yarmouth, Lynn, Scarborough, Sunderland, Aberdeen, Eyemouth, and Ramsgate. The latter he commenced in 1774, but it was not until ten years later that the first stone of the new dock was laid; and while carrying out the dockyard pier Smeaton first employed the diving-bell in building the foundations. The works when finished were found to answer remarkably well. The area of the harbour included 42 acres, the piers extended 1,310 feet into the sea, and the opening between their heads was 200 feet wide. He is said to have been proud of the pretty little harbour which he constructed at Eyemouth, as it was one that effectively suited its purpose, and cost but a small sum of money. It lies in the corner of a bay, opposite St. Abb's Head, on the Berwickshire coast, and is nearly landlocked. The canals of Birmingham, the Ure, and Dublin were improved by his skill. His work at the Eddystone made him a great authority on lighthouses, and after the erection of two (on his plans) at Spurn Point, between the years 1771-6, Government consulted him respecting the dockyards at Portsmouth and Plymouth. Professional business poured in upon him and he was ever ready "to supply a design of any new machine, from a ship's pump to a turning-lathe or a steam-engine." Water companies consulted him as to water-supply; agriculturists, as to the drainage of their lands; pit-owners, as to the working of their mines; and millers, in all matters of mill-work; he erected no less than forty-three water-mills of various kinds, and many wind-mills. His Chacewater engine, of 150 horse-power, was the finest of its kind that had then been erected. In this field of invention he was certainly distanced by Watt, the superior merit of whose condensing-engine he frankly admitted. While thus finding extensive employment in the three kingdoms, Smeaton continued to reside at Austhorpe, where he had been born. The mechanical experiments of his boyhood had been conducted there in an outhouse given him by his father, and there, in maturer and wealthier years, he erected a mansion, with a workshop, a study, and observatory all in one, for his own use. The latter was in the form of a square tower. On the ground-floor stood his forge, on the first-floor his lathe, on the second his models; the third was his study, where he drew his plans and wrote reports; the fourth was a lumber-room, from whence a tunnelled staircase led to the roof, where a vane, which worked a dial in the ceiling, could inform him, by merely raising his eyes, which way the wind blew. One of his maxims was, "Never let a file come where a hammer can go." He was a frequent witness before committees in Parliament concerning bills for the erection of public works, and when in London his chief pleasure was to attend the meetings of the Royal Society. In all difficult professional matters his advice was almost

invariably followed—a proof, not only of his eminence as an engineer, but of his judgment, caution, and integrity. But John Smeaton's useful public life was drawing towards its close. In 1783 his health began to decline, and he retired from active business. His wife died in the following year, and his two daughters kept house for him at Austhorpe, where, after being stricken with paralysis, he died on the 28th of October, 1792, in his sixty-eighth year. He was laid among his forefathers in the old parish church at Whitekirk, where there is erected a monument to his memory, and above it is placed a model of his greatest work, the Eddystone Lighthouse.

FORTIFICATION.—V.

BY AN OFFICER OF THE ROYAL ENGINEERS.

CLOSED WORKS.

THE points to be attended to in the design of fortifications have already been alluded to; but, in order to understand the relative merits or defects of the various forms of closed works usually met with, it will be best to consider in detail each of these primary conditions, and to omit from present consideration all permanent forts or fortresses.

These latter are in themselves *closed works*, but are generally on such a large scale that they may with advantage be studied separately, as embodying the most approved theories of defence held by the military engineers of a particular nation or period.

Conditions to be fulfilled by Closed Field-works.—In arranging the design of a closed work it will be necessary to determine—

1. The size necessary for the accommodation of any given force.
2. The shape that will be best adapted to the peculiarities of the ground, and to the special defensive objects in view.
3. The modifications of the trace that will be required to ensure a reciprocal defence between the various parts of the work.

Size.—The size of a work depends not merely on the number of men and guns actually required for its defence at any particular moment, but also on whether the defence is intended to last for any length of time, and whether the garrison are to be entirely restricted to the possession of their works.

In the latter case, provision must be made for the fighting space necessary for the men, guns, and the magazines, etc., belonging to them; and there must also be sufficient room in the interior of the work either for an encampment, or for the construction of buildings to serve as barracks.

It rarely happens that field-works are so completely isolated as to require accommodation of this kind for more than a small portion of their garrison, and the length of the sides or faces of a work are, therefore, usually calculated on the space required for the defence itself.

For this purpose it is usual to allow 1 yard lineal of parapet per man, if it is to be defended by single rank, or per file (two men) if double rank are to be employed. A field-gun firing at right angles to a face requires a space of 5 yards lineal to work in; and when a gun is placed at an angle, provided the angle is not very acute, 5 yards on either side of it must be allowed

Under most circumstances, when the works are of moderately regular shape, the above rule will give ample interior space; but should the shape of the ground necessitate the interior space being much cramped, it must be remembered that, exclusive of the space occupied by traverses, slopes, etc., a minimum of 15 superficial feet per man and 600 superficial feet per field-gun is requisite.

The dimensions of the traverses must vary with the circumstances of each case. On faces liable to enfilade or reverse fire they must be of considerable thickness, to intercept the enemy's projectiles; whereas when they are only intended to protect from the splinters of shells bursting in the work, they need not exceed 6 or 8 feet in thickness.

In addition to the number of troops required for the primary defence of the parapet, a reserve should invariably be allowed for, who should be kept under cover close at hand, to replace casualties, and repel any temporary success that may be gained by the assaulting columns of the enemy.

It may often be necessary to determine the requisite garrison for a work already existing; in which case, deduct from the total length of crest-line the space occupied by the guns and each face, and estimate for the remaining parapet as if to be defended by double rank. The number so obtained will be the total infantry garrison, to which the requisite number of gunners for the service of the artillery must be added.

Occasionally it may be necessary to construct closed field-works near the coast, containing batteries, where the heaviest artillery are to be employed; under these circumstances the dimensions already given must be largely exceeded. As much as 20 feet lineal of parapet are required for working a heavy gun with a lateral range of 60°.

These guns must be placed at intervals of 46 or 50 feet, and a traverse provided for every pair of guns; in addition to which an ample allowance must be made for the space occupied by the magazines, shell-filling rooms, and other adjuncts necessary for the service of modern heavy ordnance.

Closed field-works have, on different occasions, been constructed of very varied sizes, as will be seen from the following extract from a memorandum of Sir J. Jones on the celebrated lines of detached works thrown up at Torres Vedras, by order of the Duke of Wellington:—"The redoubts were made of every capacity, from that which—limited by want of space—was occupied by 50 men and 2 pieces of artillery, to another which was occupied by 500 men and 6 guns."

It may, however, be safely affirmed that all small closed works are bad, and are incapable of maintaining a prolonged resistance to the powerful shell-fire of rifled artillery, unless a greater amount of protection is provided than is usually possible to obtain in the field.

Not only does the fire directed against one side of the work necessarily take in reverse the opposite faces, and thus necessitate such a number of traverses as to seriously cramp the interior space, but the garrison, being crowded into a small area, must suffer fearfully from the effects of shells bursting among them.

The small redoubts which defended the Danish position of Düppel, in 1864 (Fig. 35), are examples of this, for it appears (*vide* "Austrian Military Journal," 1864) that on that occasion the fire of the Prussian artillery rendered the interior of the works so untenable that, at length, in order to obtain more cover, the troops were, to a great extent, temporarily withdrawn from them to a more secure position a short distance in rear, and that one redoubt (No. 5) was stormed by the Prussian troops before the Danes could re-enter their own work.

Shape to suit the ground.—The object of a work may be either that of occupying a particular site, so as to thoroughly defend the approaches to it; or else—although capable of resisting attack on any side—it may be specially designed to bring a heavy fire to bear in certain directions only, its own front being protected by the fire of some collateral works. In the former case the outline or trace must adapt itself closely to the contour of the ground, while in the latter the longest lines of parapet must be those firing in the required direction, irrespective of whether the best possible close defence is thereby attained.

Care must be taken in all cases that the main lines are, if possible, so traced as to be secure from enfilade.

The combination of these principles is by no means easy when the ground to be occupied is irregular, and when there are commanding points within range which may be seized by the enemy; the result being usually a compromise between what is theoretically perfect and what is defective but practicable.

As soon as a general idea of the outline of a work has been decided on so as to carry out the required objects, it then becomes necessary to fit the plan to the ground, so that all the approaches may be thoroughly defended by the fire from the work. In doing this it will often be necessary to modify both the plan and profile previously determined on.

There are certain limits, depending on the slope of the ground, within which the crest-line may be advanced or retired from the top or crest contour of a hill without sacrificing the power of efficiently defending the slopes. As will be seen from Fig. 36, the greatest distance to which it can be retired from the crest will be that which causes the line of fire to graze the slope of the hill, while the minimum distance will be that which allows of the fire passing at such a height above it (3 feet) as shall render it impossible for a body of men to advance unseen. In

this sketch it is, of course, assumed that the parapets are of the same height.

Any further deviation from the crest-line of the hill will involve an alteration of height for the profile, unless it happens that the ground is so steep that, with a small amount of labour, it can be scarped or rendered inaccessible, in which case defence by direct fire is not wanted, and the distant flank fire of another work will suffice.

Flanking Defence.—The provision of a really formidable flanking defence in field-works is always a problem difficult to solve satisfactorily. Their ditches are usually so narrow, and the time necessary for crossing them so short, that it is very desirable the flanking fire on the attacking troops should cover the ground in advance of the counterscarps as well as the ditch itself. To do this, the fire must proceed from the parapet, and an arrangement of trace becomes necessary that has many serious defects. The necessarily increased length of parapet involves more labour, and some of the faces become unavoidably liable to enfilade.

Works in which the fire from the parapets of the flanks defends the ditch are called *forts;* and those in which there is no flank defence, or where the ditches are flanked by parapet called *curtains.* The combination of any two bastions and a curtain is termed a *bastioned front;* and when a bastioned front is traced on each side of the polygon or imaginary figure containing the work, it is called a *bastioned fort.* In a properly-constructed bastion fort, when there has been sufficient time to complete the necessarily wide ditches, the reciprocal defence of the various parts of the work is good; but, on the other hand, the bastions are liable to enfilade and reverse fire, and the length of parapet to be constructed and manned is so very considerable that the interior space would be too much cramped to render this trace advisable for any but large and important positions. To ensure efficient flank defence, without risk of the fire from the flanks striking the defenders of the opposite bastions, care must be taken that the angles of defence are never less than 90°.

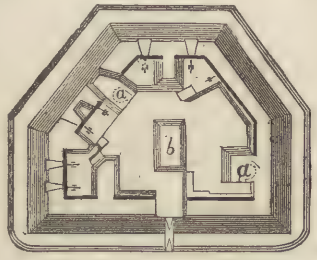


Fig. 35.—REDOUBT AT DÜPPEL.

It has been found advisable to fix on certain proportions between the various lines of construction, in order to get the best defence possible; and as these proportions are dependent on the size of the polygon on which the fronts are designed, it may be well to state in order the operations necessary to enable a student to draw the trace of a bastioned front (Fig. 39).

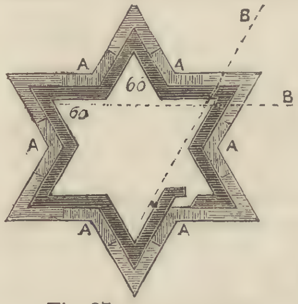


Fig. 37.—STAR FORT.
A, A, A, Undefended Ground in the Ditches.

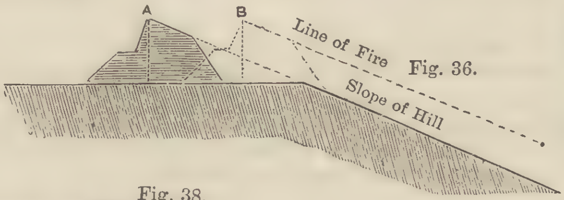
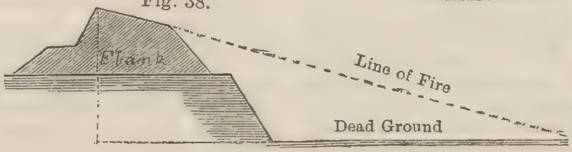


Fig. 36.

Fig. 38.


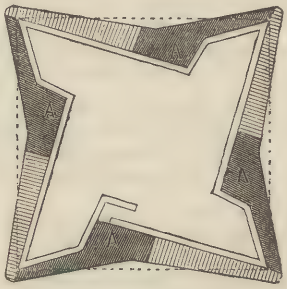


Fig. 40.—DEMI-BASTIONED FORT.
A, A, A, Dead Ground in Ditches.

buildings in them, are termed *redoubts.*

Forts are not so generally applicable to irregular sites as *redoubts*, and require more time for their construction. There are two types of fort of regular form, viz., the *star fort* and the *bastioned fort*, although a modification of the latter is sometimes employed, called the demi-bastioned trace. This only partially attains the advantages of the bastioned system, as regards flank defence (Fig. 40). In order to obtain flank defence, the parapets of a star fort are traced so as to form a number of salient and re-entering angles, thus giving a star-shaped outline (Fig. 37).

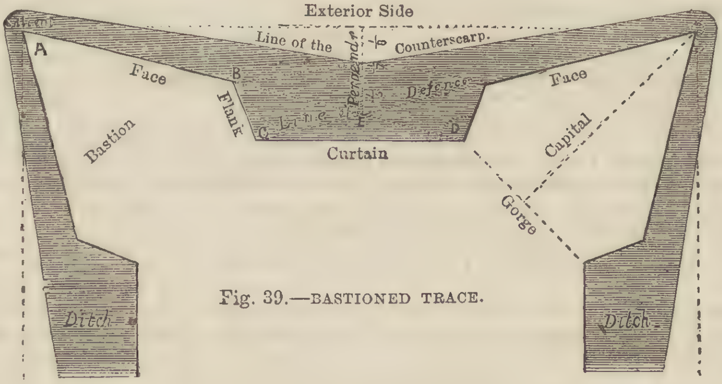


Fig. 39.—BASTIONED TRACE.

Star forts have many defects, of which the following are the chief. The length of parapet is excessive, in proportion to the area they enclose. All the faces are liable to enfilade and reverse fire, and a portion of each ditch near the re-entering angle is necessarily unseen, and therefore undefended by the fire from the parapets (Fig. 38). The amount of this undefended space in the ditch, or *dead ground*, as it is called, is estimated by multiplying the relief of the flank by the inclination of the line of fire, and is measured on plan from the crest-line, in the direction of the ditch.

A *bastion* is a lunette connected with other works by lines of

1. Bisect the exterior side by a perpendicular line drawn inwards; and make this line $\frac{1}{8}$, $\frac{1}{7}$, or $\frac{1}{6}$ of the exterior, if the polygon of construction is a square, pentagon, or any larger figure.

2. Join the end of the perpendicular with the angles of the polygon, and produce these lines inwards. These are called the *lines of defence.*

3. Set off on each line of defence a distance equal to $\frac{1}{3}$ of the exterior side, measured from the angle of the polygon. This will give the *faces of the bastions.*

4. From the ends of the bastion faces draw the *flanks*, making angles of 95° with the opposite lines of defence.

5. From the points at which the flanks cut the lines of defence, draw a straight line connecting the inner extremities of the flanks. This will be the curtain.

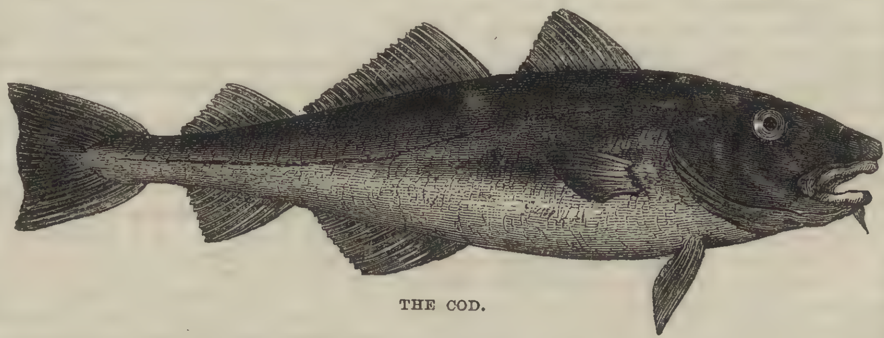
In order that the whole fire from one flank may defend those parts of the ditch unseen by the other, it is necessary that the lines of fire should cross at the centre of the curtain, and that the line of the counterscarp should not be traced parallel to the escarp, but be directed on to the shoulder angles of the bastions. As will be seen in the sketch (Fig. 40), this latter arrangement increases the width of the ditch considerably, and consequently involves much time and labour to execute.

ANIMAL COMMERCIAL PRODUCTS.—XII.

PRODUCTS OF THE CLASS PISCES (*continued*).

THE COD (*continued*).

It is the great quantity of cod and its allied kinds, haddock (*Morrhua æglefinus*), tusk (*Brosmus vulgaris*), and ling (*Lotus mola*), which gives to these fish their chief mercantile importance. In 1854, 3,523,269 individual fish of the cod and ling kind were caught, of which 1,385,699 were from the Orkney and Shetland Islands, and the remainder from the other fishing stations on our coasts. In 1857 the total amount of cod, ling, and haddock taken by the fishermen of the United Kingdom was: Cured and dried, 104,668½ cwt.; cured in pickle, 4,393½ barrels; cured, dried, and exported, 34,310 cwt.



THE COD.

The greatest cod fishery in the world is on the banks of Newfoundland. These banks are based on a large rocky shoal about 600 miles in length and 200 in breadth, being, in fact, the top of a vast submarine plateau, over which the ocean rolls. This place is a great rendezvous for cod, which resort there to feed on the worms, which are plentiful in these sandy bottoms, and on account of its vicinity to the polar seas, whither they return to spawn. The cod are found here in such numbers that although maritime nations have for centuries worked indefatigably at these fisheries, not the slightest preceptible diminution of their abundance has ever been noticed. The Newfoundland cod fisheries are carried on now principally by the French and Americans. The British interest in them has declined of late years very considerably, as we have transferred the site of our operations to the coast of Labrador, where 20,000 English sailors, with from 200 to 300 schooners, are annually employed. The Americans fit out their vessels chiefly at Boston, and thus from their vicinity to these fishing-grounds possess a great advantage over the English. Immense quantities of cod are sent by England, France, and Holland, partly salted and dried to Southern Europe, chiefly for consumption during Lent and the other fasts of the Roman Catholic Church.

THE FLOUNDER, SOLE, AND PLAICE.

Turbot (*Rhombus maximus*).—Taken on all our coasts. The English markets, however, are supplied chiefly with Dutch turbot, which is preferred; these are caught on the sand-banks lying between Holland and the eastern coast of England. The Dutch receive £80,000 per annum for supplying the London markets with turbot; and the Norwegians £15,000 for about 1,000,000 Norwegian lobsters, used partly as sauce for turbot.

Sole (*Solea vulgaris*).—The sole is common on the British coasts, and in season from May to November. The principal fishing stations are on the south coast, from Sussex to Devonshire, especially at Brixham and Torbay. *Plaice, flounders, dabs, halibuts*, etc., are all in great request in the market, but can only be mentioned.

Lamprey (*Petromyzon marinus*).—An eel-like cartilaginous fish, having a funnel-shaped mouth, surrounded by a circular suctorial lip, by means of which it adheres to stones (Greek, *petron*, a rock; and *muzo*, I suck) and to the bodies of those fish on which it feeds. Formerly the lamprey was considered a great delicacy, and one of our kings (Henry I.) is said to have died in consequence of eating too freely of it. Although not so much in demand now, great numbers are still furnished from the North Sea, the Baltic, and the German rivers, where they abound. Lampreys reach this country packed in jars with vinegar, spices, and bay leaves.

Common Sturgeon (*Acipenser sturio*) belongs to the group of cartilaginous fishes. The body is elongated, spindle-form, and usually from five to six feet in length; the head, which is depressed and produced into a triangular snout, is covered with rows of large tubercular bony plates. The sturgeon is abundant in the seas of Northern Europe, also in the Caspian, the Black Sea, and the Mediterranean, ascending the rivers in great numbers to spawn.

Caviare, which forms an important article of commerce, consists of the roe of different species of this fish, cleaned, washed with vinegar, salted, dried, and then compressed into small cakes, or packed in kegs. Russian caviare—brought from the Caspian and Black Seas—is usually considered the best. Much caviare is also prepared on the shores of the Lower Danube. That furnished by the sterlet (*Acipenser ruthenus*) is so superior that, according to Cuvier, it is reserved for the imperial court of Russia.

Isinglass, another product from these fish, is prepared from their air-bladders. This substance owes its commercial value to its extremely delicate fibres, which operate mechanically in the clarification of white wines and malt liquors. It is also much employed in cookery. Russian isinglass is preferred to that from Hungary and Germany.

PRODUCTS OF THE SUB-KINGDOM MOLLUSCA.

Mollusca (Latin, *mollis*, soft).—Soft-bodied, invertebrated animals, devoid of an internal bony skeleton, having a gangliated nervous system, the ganglia, or knots of nervous matter, being irregularly dispersed in different parts of the body. They

have a distinct pulmonary or branchial circulation, white or bluish blood, and in most cases a shell covering, in which the animal resides. This is secreted by the margin of a peculiar organ termed the mantle, or an external fold of the skin reflected over the body. Many of the lowest and some of the highest of the Mollusca are naked, or a horny and testaceous rudiment of a shell is developed, but remains concealed beneath the substance of the mantle. When, however, the shell is so much enlarged that the contracted animal finds shelter within or beneath it, then the mollusk is termed testaceous (Latin, *testa*, a shell). We shall confine our notes to the testaceous Mollusca, as commercially they are the most valuable. The following are the chief classes of the Mollusca :—

1. *Cephalopoda*, or *head-footed* (Greek, *kephale*, head, and *pous*, a foot), having the head well developed, protruding from the mantle, and furnished with tentacula, serving for the seizure of food and for crawling. Examples : nautilus and cuttle-fish.

2. *Gasteropoda*, or *belly-footed* (Greek, *gaster*, the belly, etc.), crawling by means of a broad muscular disc on the lower surface of the body, which serves as a substitute for legs. Examples : *Helix hortensis*, the garden snail ; *Lymnœa stagnalis*, the pond snail ; and *Limax agrestis*, the field slug.

3. *Pteropoda*, or *wing-footed* (Greek, *pteron*, a wing, etc.), comprehending a few mollusks which have a natatory wing-like expansion on each side of the head. They are naked, or provided with a delicate univalved shell. Example : *Clio borealis*. Most of the species of the class *Pteropoda* are fossil, but a great many are still found in existing seas, living near the surface.

The *Clio borealis* forms the food of the whalebone whale. It is an inch long, uses its light shell as a boat, its wing-like fins as oars, and so navigates, in countless numbers, the tranquil surface of the Arctic seas.

4. *Conchifera*, or *shell-carriers* (Latin, *concha*, a shell, and *fero*, I carry), including all the bivalved mollusks not *Brachiopods*. Examples : oyster, mussel, and pearl oyster.

5. *Brachiopoda*, or *arm-footed* (Greek, *brachion*, an arm, etc.). —Bivalves devoid of locomotive power, and attaching themselves to foreign bodies : they are furnished with two long ciliated arms developed from the sides of the mouth, which, by producing currents, bring food to the animal. Examples : *Terebratula* and *Lingula*.

APPLIED MECHANICS.—VII.

BY ROBERT STAWELL BALL, M.A., LL.D.,

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MACHINERY USED IN AGRICULTURE.

MECHANICAL APPLIANCES USED IN PREPARING THE SOIL —MACHINES USED FOR SOWING—MACHINES USED IN REAPING.

THE application of machinery to the different branches of agriculture is of considerable antiquity. Not to mention the simple implements such as spades, rakes, etc., more complicated machines have been in use since the earliest times. A form of plough which was used by the ancient Romans is still employed in parts of France and Italy. The ploughs with which we are familiar are, in fact, to a certain extent on the type of the ancient instrument, but have received from time to time improvements which the experience of successive generations of cultivators of the soil has suggested. The Romans were also accustomed to irrigate their land by artificial means when circumstances were suitable, and this process is still recognised as one of the most scientific applications of capital to agriculture. In this lesson, however, we propose rather to sketch the present condition of agricultural machinery than to trace its history in successive ages. There are other applications of science to agriculture besides those which relate to the employment of machinery; notably among these is the service rendered by chemistry in the analysis of soils and manures : with such matters we have nothing to do. This lesson is intended to describe the mechanical appliances employed, first, in the preparation of the soil; secondly, in the putting in of the crop; and, thirdly, in the gathering of the crop. Those who wish to pursue the subject further will find a considerable amount of information in Donaldson's "British Agriculture," a work to which I must acknowledge my obligations in the preparation of the present lesson.

MECHANICAL APPLIANCES USED IN PREPARING THE SOIL.

Land may suffer on the one hand from an excess of water, on the other hand from a deficiency in that fertilising liquid ; in either case mechanical appliances must be resorted to as a remedy. In the one case we must by drainage endeavour to remove the superfluity, in the other case by irrigation we can supply the water which is necessary. There is no occasion, however, to do more than mention these important operations here, as the various methods employed for carrying off surplus water from the soil by artificial means, and distributing fertilising currents over parched grass-lands, are fully described in the lessons in "Agricultural Drainage and Irrigation" given in this work.

Drainage and irrigation are most necessary mechanical operations in the treatment of the soil prior to its being actually broken up for the purposes of tillage. To this important subject we now proceed. The earth is a very weighty material, and the labour that is expended upon breaking it up consists in great part of the actual exertion of raising its weight through a small height and replacing it again. Thus the soil that covers an acre to the depth of four inches weighs from 600 to 700 tons, and if in the process of breaking up this mass has to be raised even to the height of a few inches and replaced again, the consumption of work is very considerable. But in addition to the mere weight of the soil, there is its tenacity also to be overcome. It is probable that in many soils, if not in most, the force requisite to overcome this exceeds that which is due to the weight of the soil alone. Thus in digging a garden with a spade, though the sharp edge of the spade divides the soil, yet the mass that is being removed has to be torn away from the lateral portions, and in tenacious soils, as every one knows, this resistance is very great. A spade is, in fact, a powerful lever of the first order. The power is applied by the hands at one end, the fulcrum is the upper portion of the spade where it is in contact with the surface of the soil, and the load is the mass of earth which is being removed. The leverage in such an implement is at least sevenfold or eightfold, and even with this mechanical advantage the operation of digging is one of great labour.

On the large scale, the use of the spade is, of course, replaced by the plough. We here abandon the principle of the lever as a mechanical power, but we replace it by the wedge which we have already described. In reality the ploughshare is a wedge which inserts itself into the soil, and overcomes both the resistance of the weight of the soil and also that presented by its tenacity.

It will be well to mention the names which are applied technically to the different portions of a plough. We shall then consider the principles on which the action of the plough depends. The bottom of the plough is called the *sole*; to the point of this is fixed the *share*; the beam projects in the front of the plough, and to it the oxen or horses are attached. Attached to the beam in a vertical position is the *coulter*; this cuts a vertical section in the ground; while the point of the share, expanding into a fin, cuts a horizontal slice from the ground under it. The *mould-board* is placed behind the fin, and serves to raise up and remove the slice which has been cut by the coulter and share. These different portions of a plough will be seen from the illustration of a very improved form of plough (Fig. 3).

The action of the plough is therefore threefold. First, the vertical cut by the coulter, then the horizontal cut by the share, and, finally, the turning over of the portion thus cut by the mould-board. Experience has done more in devising the form of the plough than direct application of science. The actual problem of finding the best possible form of plough would be a very difficult one, even if all the conditions of the question were known; but owing to the varying conditions of soil, it is almost impossible to devise any very rigorous statement of the problem which the best construction of a plough would involve. We shall, however, give a short account of what is known as to the principles on which the plough acts. The accompanying figure (Fig. 1) is taken from the "English Cyclopædia," in which an excellent account of the theory of the plough will be found. Let A B D C represent the slice of ground which is being re-

moved by the plough; A C is the vertical cut which is made by the coulter; C D the horizontal cut which is made by the share. The object of ploughing is to turn this sod up to the vertical position, D *c a b*, and then to tilt it over to the inclined position, *d′ b′ a′ c′*, so that the original surface, A B, is changed into the under surface, *a′ b′*; the object of this is to kill the weeds or grass that may be on the surface by burying them, and at the same time to expose as much of the soil as possible to the action of the atmosphere. The problem, then, which the mould-board has to solve, is to effect this operation as uniformly and with as little waste of power as possible. This condition points out that the surface of the mould-board must be that of a screw, which might be produced by a line nine or ten inches long, which revolved uniformly about an axis through an angle of 135°, while at the same time it travelled along the axis through a space of three or four feet.

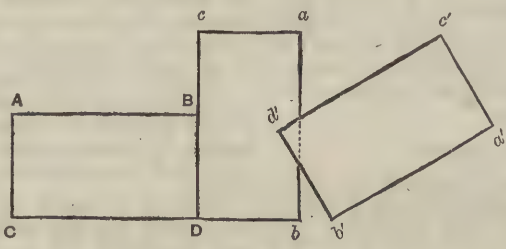


Fig. 1.

The portions of a plough are now generally made of cast-iron, and a very beautiful property of cast-iron is made use of in the point of the share. It is well known that cast-iron when poured into an iron mould becomes intensely hard. It is called chilled iron, and is used where ordinary cast-iron would be too soft. In casting the share, the lower surface of its point is in contact with iron; the consequence is that the under surface of the share is of chilled iron, while the upper surface is of ordinary cast-iron. The effect is that the upper part of the point is worn away more rapidly than the under surface, and consequently the share always presents a sharp edge. The actual draught required in drawing a plough is very variable; but it may, on the average, be taken at about three hundred-weight. This point is carefully attended to in comparative estimates of the merits of different forms of plough. It is ascertained by attaching a dynamometer to the plough, and applying the power of the horses to the dynamometer.

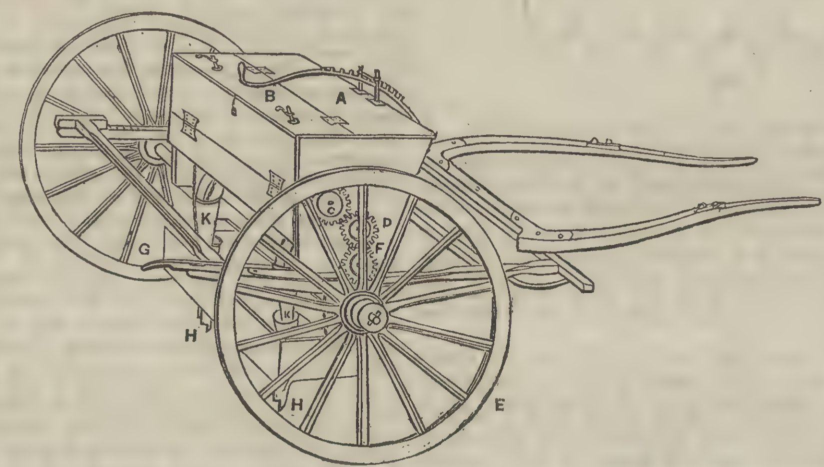


Fig. 2.

It is usual now to employ, when the circumstances will admit of it, steam power for drawing ploughs, in place of the muscular power of animals. To render this plan capable of economical adoption, a large area must require to be ploughed, and the land should be tolerably level. The steam-engine which gives motion to the ploughs is in one corner of the field, and its power is communicated by means of wire ropes, which passing over pulleys properly attached at the margin of the field, are fastened to the ploughs. One engine is thus enabled to work several ploughs simultaneously.

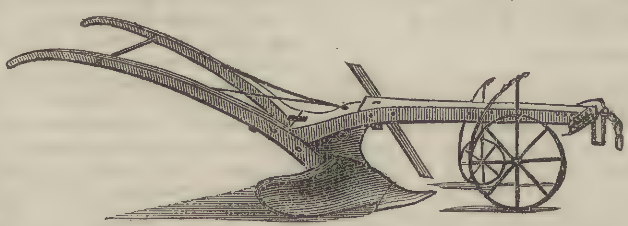


Fig. 3.

The next operation to which the land is subjected is that of harrowing. This is of a very simple character; it consists merely in drawing a frame covered with spikes over the newly-ploughed fields, for the purpose of breaking up the clods which the plough has turned up. Nothing further need be said of this process.

MACHINES USED FOR SOWING.

In sowing, it is desirable that the seed be distributed with regularity over the surface, and in the quantity which experience has found most desirable for each kind of seed. It is also necessary that the seed be deposited at precisely that depth in the soil at which it will be most favourably circumstanced for germination. Now machinery, by the regularity and certainty of its action, is eminently adapted for the purpose of placing seed at the right depth and in proper quantity. It is not, therefore, merely as a labour-saving agent that sowing machines are useful; they accomplish the work with a perfection that it is not possible for labour unassisted by their means to attain. It is found that seeds sown in drills yield a crop more economically than when the seeds are sown broadcast. The machines which are employed in sowing are therefore adapted for depositing the seed in drills. These machines are themselves technically called *drills*, in consequence of the object for which they are employed. In Fig. 2 is shown what is called the Northumberland turnip drill, used, as its name expresses, for sowing turnip seed. It is a very perfect instrument of its kind, and a description of it will embrace the principal features of all the better machines of this class. We have borrowed this figure, and the accompanying description of it, from the "English Cyclopædia."

This machine is adapted to introduce ground bones, or other manure of the same class, into the ground simultaneously with the seed. "The body of the drill consists of two boxes, A and B, divided by a partition between them, and each again divided into two by another partition at right angles to the first. Into the box A is put the manure, into B the seed. Iron slides are fixed on each compartment to regulate the supply of seed or manure. In the lower part of the box, and just before the opening, which is regulated by the slides, are two cylinders, one for the box A, and the other for B. On the cylinder in A are fixed shallow cups with short stems which dip in the boxes, and carry a certain quantity over the cylinder as it turns, which falling in the funnels, K, K, is deposited in the furrows made by the coulters, H, H. The cylinder in the box B has projecting pieces of iron with a small cavity in each near the end, which takes up a very small quantity of seed, and discharges it in the same manner into the two funnels, K, K. On the axis of the wheel E is a toothed wheel, which turns a small wheel, D, on the axis of the cylinder in A, and thus turns

another wheel, C, on the axis of the cylinder in B. As these two wheels move towards each other, the two cylinders turn in contrary directions, which is a convenience in turning the seed and the manure into the funnels at the same time. The wheel F may be lifted up by means of a lever G, and then the cylinders do not revolve. There are various other contrivances which cannot easily be explained without a more detailed figure of the different parts." It is always difficult to convey an adequate idea of complicated machines by description: an examination of the machine itself, which is to be met with in any agricultural museum or show, will explain its action better than any description, however lengthy.

MACHINES USED IN REAPING.

We have seen how machinery aids in preparing the soil and sowing the seed: we have now to examine its utility in enabling the farmer to realise the fruits of his labour. Reaping-machines are of very modern construction; they are eminently useful as labour-savers, and simultaneously with the rise in wages of agricultural labourers have reaping-machines come more and more into use. They vary very much in external appearance, but certain principles appear to be common to all the different forms. The blade of the reaping-machine consists of a series of notches, as shown in Fig. 4. These notches are sharpened

Fig. 4.

on their edges by grinding-stones of peculiar construction. If we conceive two blades of this shape, one immediately overlying the other, and if the one be held fast and the other be made to oscillate backwards and forwards rapidly, we have the essential principle of a reaping-machine. These blades are carried a few inches above the surface of the ground, and one of them is made to oscillate by means of a mechanical connection with the wheels of the machine; a series of arms force the straw into the notches, and it is immediately cut across by the moving edges, and the machine neatly deposits the corn which has been cut.

We have in this lesson been able to give only the merest outline of the debt which modern agriculture owes to machinery. There are innumerable appliances into which we cannot enter. Thrashing and winnowing machines would form a suitable sequel to reaping-machines. We might also speak of machines for cutting down trees, for removing stumps of old trees from the ground, and machines for excavating earth. There are numerous machines in constant use in America with which we are not familiar here. There the high price of labour has rendered all labour-saving appliances of far greater economic importance than in older countries where the population bears a higher proportion to the capabilities of the soil for production.

PRACTICAL PERSPECTIVE.—I.

INTRODUCTION.

THE intimation that "these lessons are written to supply a want" has become so hackneyed, that it is only repeated here because no other sentence would so well express their real purpose; and it is hoped that by their publication a series of really elementary lessons will be given which will be useful not only to artisans and teachers, but to the public generally.

The words used in the introduction to the lessons in "Practical Geometry applied to Linear Drawing" refer equally to these lessons:—"The subject is not treated as a mathematical, but as a thoroughly practical one, and therefore no absolute system of reasoning is attempted; still, it has been thought right to give some simple and familiar explanations of the properties of the various figures, and the principles upon which their constructions are based, as it must be obvious that the more the mind comprehends of the relation of one line and form to another, the more will the eye appreciate beauty and refinement, and the more intelligently will the hand execute."

In pursuance of this plan, only just as much of the theory of Perspective is given as will enable the student to comprehend the subject; and an endeavour is made, as the lessons advance, to show the application of the principles, and of the few rules laid down.

The studies are very carefully graduated, commencing with the perspective projection of single points, and proceeding in succession to the consideration of lines, planes, and rectangular solids, in the foreground and in the distance, when parallel or at an angle to the picture.

The course next takes up the delineation of polygons, prisms and pyramids, circles, cylinders, and arches.

The examples are all clearly drawn, the working lines being shown; the lettering is plain; and the instructions as simple and brief as is consistent with the proper explanation of the subject.

Exercises are added in order that the student may test whether he has fully comprehended what he has been taught, and whether he can vary the circumstances whilst applying the principles. This will counteract the tendency to *copy* the *diagrams* so often met with.

These exercises will also be found most valuable to teachers, who are advised to write them on the black-board, causing each student in the class to take a different centre, points of distance, scale, etc., whilst still working out the subject according to the other data given.

The student is urged to work the figures contained in lessons in "Practical Geometry applied to Linear Drawing" either before, or concurrently with Perspective, as he will otherwise find himself constantly in the awkward position of being unable to construct the geometrical form which he is endeavouring to put into perspective. It will also be of advantage to him to study "Projection" either previously to, or at the same time with, these lessons, as he will then be able to observe the changes of form caused by the parallel lines of the one system and the convergent lines of the other, whilst the knowledge of developments will enable him to understand the true forms of the surfaces which become so much altered by Perspective.

All the studies are based upon the actual experience gained during nearly twenty years' teaching, in which the inquiries of students, their difficulties, and the errors into which they are most liable to fall, have been most carefully noted; and it is therefore hoped that these lessons may do the work at which they aim efficiently, so that the term "Perspective," instead of being uttered with dread, as a mysterious art known only to a few, may become as familiar as a household word to the many, and thus, by a knowledge of its principles, our students may be enabled, not simply to work out the lessons with their instruments, but to sketch with rapidity and correctness, whether from the object or from memory. *When Perspective is thus understood, it becomes indeed the grammar of a universal language.*

PRACTICAL PERSPECTIVE.

Perspective is that branch of "Projection" which teaches the mode of drawing objects, etc., as they *appear* to the eye of the spectator in whatever position he may be placed.

This appearance will, of course, be altered by (1) the distance of the object from the spectator, and (2) its position.

The moment we open our eyes a flood of light enters, and the rays which pass from the surfaces of every object are thus conveyed by the eye to the brain.

As these rays pass from the entire surrounding space through the small opening called the pupil of the eye, they are said to "converge,"* and thus form what is called the "visual angle."

Of course, the angle at which the outer rays meet depends on the size of the aperture in the eye of different persons. For perspective purposes, however, an average angle has been generally adopted—namely, that of 60°; for experience has shown that the majority of persons can see, let us say, a line, A B (Fig. 1), when the distances from A to C (the station of the spectator) and from B to C are equal to the length of the line; and it will be seen that an equilateral triangle is thus formed, the angles of which, as has already been shown in "Practical Geometry applied to Linear Drawing," are all 60°.

But the rays do not proceed from a single line, thus forming a *plane* triangle, but from the entire surrounding space. The

* *Converge.*—To incline together, so as ultimately to meet in a point.

triangle A B C is thus, as it were, rotated on the central line C D, and a cone (that is, a *solid* triangular body having a circle for its base) is formed. The line C D, or axis on which the triangle has been rotated, is called the central or principal visual ray.

It will be clear, then, that since the base of this cone (Fig. 2) comprehends all that can be seen when looking straight forward, our entire picture must be contained within it.

The apex, C, of the cone is called the *station-point*, as being the other. Now let threads attached to the angles of the cube pass through small holes in the plane in straight lines to the eye. Then if these holes are joined by lines, the exact perspective appearance will be obtained.

Now it is easily understood that this centre of vision will be moved as we turn round, and hence some objects will gradually be removed from our view, whilst others become visible; but so long as we do not stand on higher or lower ground, the *height* of our eye will remain the same.

Fig. 1.

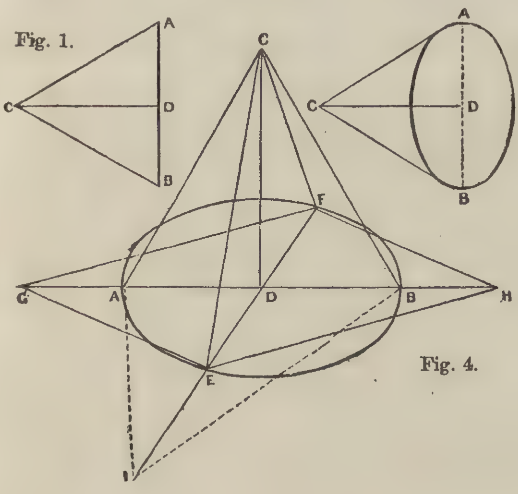


Fig. 2.

Fig. 4.

Fig. 5.

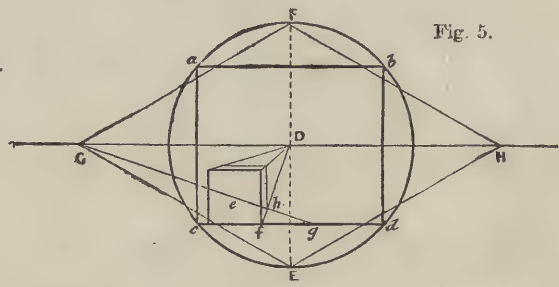


Fig. 6.

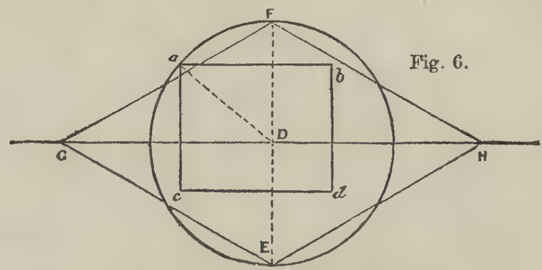
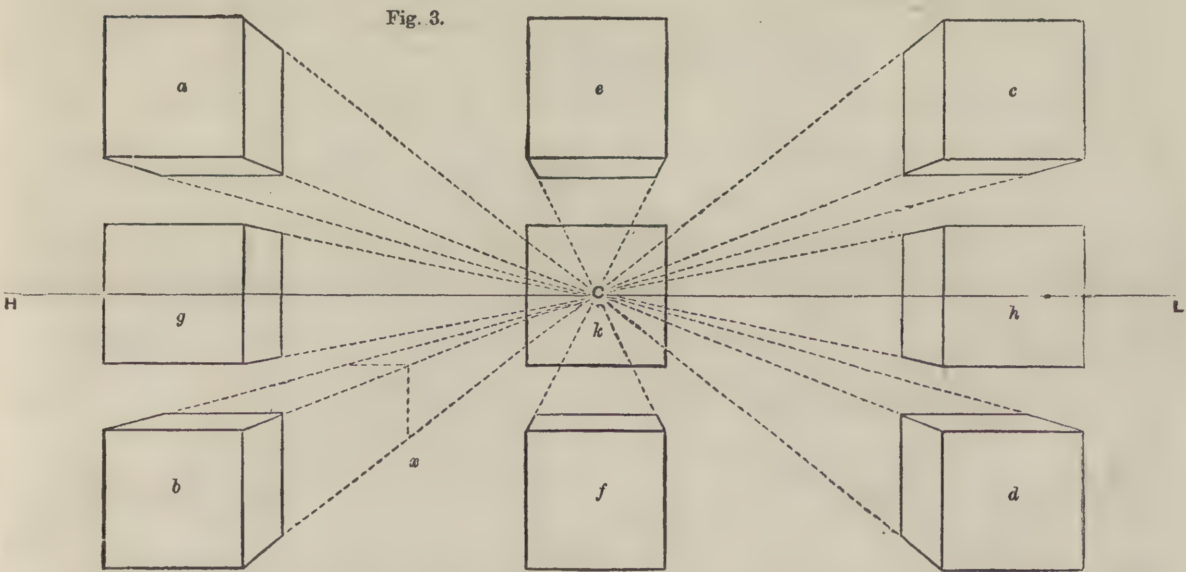


Fig. 3.



the station of the spectator, or the *point of sight*, since it is the point from whence the sight is obtained.

The opposite end of the central ray is the centre of the base of the cone of rays, and is therefore called the *centre of vision*.*

The surface on which we draw is called the *picture-plane*. It is supposed to be transparent, and (as a rule) to be placed vertically between the spectator and the object; the rays passing from the object through this plane give the apparent form. Thus, let a plane stand on its edge on a table, and let a cube be placed on one side of it, the eye of the spectator being on

The *horizontal line* is a line drawn through the centre of vision in a horizontal position, as its name implies. It shows the height of the eye of the spectator in relation to the objects drawn. This is shown in Fig. 3.

Here C is the centre of vision, and H L the horizontal line. The cube lettered *a* is above the level of the eye of the spectator, and *b* is below. Thus the under surface of *a* and the upper surface of *b* are seen. Both are on the left of the spectator, and thus the right side of each is visible.

The cubes *c* and *d* are similarly placed as to the horizontal line, but being on the right of the spectator, their left side is presented to view.

The cube *e* is above and *f* below the horizontal line, and thus the bottom of the one and the top of the other is seen; but as

* As, however, in looking forward from the point of station, the point C (the one end of the central ray) is immediately in front of the centre of the circle, the point has generally been termed the "point of sight."

they are immediately above and below the centre of vision, neither side is visible.

Again, the cube *g* is on the left and *h* is on the right of the spectator, but both are on a level with the centre of vision, and therefore only the side of each is seen, but neither top nor bottom; whilst in *k*, which is immediately opposite to the eye of the spectator, none of the sides, excepting that which forms the front, are visible.

It is necessary, however, to fix in a definite manner the positions of the lines which represent the distant edges of the objects, for it will be evident, on referring to the cube *b*, that if these were placed at *x*, the object would appear a long balk of timber instead of a cube. The correct proportion is, however, obtained by means of points, of which we shall now speak.

The *points of distance* represent the distance of the eye from the picture.

To illustrate this, let us now turn to Fig. 4. Here A B C is the cone of rays standing on its base. Now, as the picture-plane forms a part of that base, it will be clear that the length of the axis, or central ray, C D, represents the distance of the eye (situate at the apex of the cone) from the picture, and it is now required to lay this length down on our paper.

It has been said that the cone adopted for the purposes of perspective has its slanting side equal to the diameter of its base. Therefore any section taken through the axis would be an equilateral triangle, as E C F.

Now, if we imagine this equilateral triangle rotated on the line E F, first on the one side and then on the other, we shall obtain G and H, which will be the points of distance, for D G and D H will be equal to D C, the altitude of the triangle or axis of the cone, which is necessarily the distance of the spectator from the picture.

Fig. 5 is the plan of this cone.

Having drawn the picture-plane, *a b c d*, and the base of the cone surrounding it, draw the perpendicular line E F.

From E and F, with radius E F, describe arcs cutting each other in G and H, which will be the points of distance.

To show at once the use of these points, draw the square *e*, and from its angles draw lines to D (representing rays of light passing to the apex of the cone).

Now from the point *f* of the cube set off what you know to be the *real* width of the distant side (which in this case will be equal to the width of the front, the object being a cube), namely, *f g*.

From *g* draw a line to G, which, cutting *f* D in *h*, will give the point at which the distant edge of the cube is to be drawn. This figure may be slightly in advance of the student's present knowledge, and is merely introduced here so that the purpose of the points of distance may as soon as possible be made evident. The steps leading to this subject will, however, be clearly shown hereafter.

The centre of vision, although the centre of the base of the cone of rays, need not necessarily be the *centre* of the *picture*, for although the picture-plane must be contained within the circle, it need not occupy the whole, but it *must* touch the circumference at *one* point.

To find the points of distance when the picture-plane, *a b c d* (Fig. 6), and the centre of vision, D, are given—

Through D draw the horizontal line.

From D, with radius D *a*—that is, from the centre of vision to the most distant angle of the picture-plane—describe the base of the cone of rays.

Draw E F through D, and with E F as radius, describe arcs cutting each other in G, H, which, as before, will be the points of distance.

The bottom line of the picture, *c d*, is called the *picture-line*.

It is not always necessary to employ the whole of the picture-plane or base of the cone of rays; it is, therefore, generally enough to state the height of the eye of the spectator, and his distance from the picture. This plan will now be adopted, as we shall be thus enabled to employ the whole space at our disposal in delineating the subject of the study. The centre of vision will throughout the lessons be called C, and the points of distance, P D. It may also be as well to remark that wherever it is necessary to speak of the horizontal line and refer to it by letters, the letters H L will always be used to denote it.

TECHNICAL EDUCATION ON THE CONTINENT.—X.

BY ELLIS A. DAVIDSON.

THE GRAND DUCHY OF HESSE.

THE POLYTECHNIC SCHOOL AT DARMSTADT.

DURING many years past there had existed in Darmstadt, under the names of Higher Trade Schools and the Technical School, institutions for the promulgation of Technical Education. They were tolerably successful and were well attended, and many men, who have since become celebrated as professors, engineers, architects, and public officers, proceeded from these schools.

The objects of both these institutions were precisely the same, but a complete education was not given in either; and students had to proceed to various establishments, mostly in other places, to obtain instruction in higher or special studies. This, again, led to the establishment of other schools for various branches; and thus a falling-off in the numbers in the two original schools took place. In 1868, however, the Legislature and the promoters of the separate schools united, and from this amalgamation the Polytechnic School at Darmstadt arose, as a High School for technical education adapted for persons of all grades of society and of every trade, admirably organised in every respect, and possessing a staff of nearly fifty professors and teachers, all men of the highest standing, working out a system well considered and complete, in a manner which must have a lasting effect, not only on Germany, but possibly on Europe generally —we may say on the world; for who can tell where the seeds sown by education may not be carried? And when we see swamps drained, deserts watered, and canals made which unite sea to sea, and know that these are some of the works of European engineers, we cannot but feel that the words spoken in the class-rooms are like so many rays of sunlight, which, though they may be buried in the mind of the student for many long years, will rise again (even as the light of thousands of years ago is now evoked from the coal mine), perhaps in far-distant lands, to illumine aboriginal darkness, and to spread the laws of God (and is not science His law?) amongst the savage and ignorant. The Polytechnic School at Darmstadt, then, is a higher technical school, professing to give a complete course of instruction for the various branches of the higher walks of industry, together with the required art-knowledge, accompanied, wherever possible, by actual practice. The studies are therefore arranged to suit the necessities of the architect, engineer, machinist, practical chemist, manufacturer, pharmaceutist, agriculturist, land surveyor, and all others whose vocations are based on scientific principles; whilst the general knowledge imparted is such as cannot fail to be eminently useful in every walk in life.

The School is divided into the following departments:—

1. The General School.
2. The School of Practical Architecture.
3. The Engineering School.
4. The School of Mechanical Construction.
5. The School of Technical Chemistry.
6. The School of Agriculture.

The studies in the general school comprise mathematics, and natural history in its widest sense, the courses being so arranged as to prepare pupils in every way for entering the higher departments of the institution, or any of the special classes they may subsequently select.

The instruction in the Polytechnic Institute is given in the form of lectures, questions, repetition examinations, graphic and constructive practice, work in the laboratory, and excursions to various factories, building works, etc., whilst immense benefit arises from the personal intercourse between the masters and pupils.

The teachers are either members of the absolute school staff or persons called assistants, who lecture on or teach the practice of their particular vocation. An amount of practical skill is thus brought to bear, which others, however highly educated they might be, could not possess.

The head of every department is, however, a professor holding a high University degree.

Private persons also, who have made some particular branch of science or art their study, and have become celebrated in it,

or who are the authors of some important invention, are from time to time invited to give lectures, and by this means the interest of the students is awakened, and their knowledge brought up to the state of science as developing around them.

The appliances for carrying out the objects of the School are very complete, and include the museums, laboratories, and collections of the two original schools, the botanical garden, and fields for agricultural experiment. The models used for teaching projection, and those for illustrating the principles of mechanism, are admirable; they will be described further on. The pupils have also the use of State museums of arts and manufactures, and of all similar collections.

For admission to the lowest form of the general school, the candidates must be at least sixteen years of age. They must give proofs of their having reached the standard of instruction given in the upper classes of the "Real" schools of the country, and must be prepared to pass an examination as follows:—

1. Algebra as far as equations of the second degree, and an acquaintance with logarithms.
2. Plane geometry and the elements of solid geometry.
3. A good knowledge of the German language and style, shown in the composition of an essay on a given subject.
4. A knowledge of the great periods of general history, and of the leading events of those periods.
5. Exercises in linear and free-hand drawing.

THE GENERAL SCHOOL.

This department is organised to give a sound and practical education, not only to youths intending to enter the various trades, but also to the general public. The following is the course of studies:—

First year:—General history and literature, the German language, mathematics, descriptive geometry, free-hand drawing, the French language, religion.

The following studies are recommended:—The English language, zoology, systematic botany, gymnastics, vocal music, Latin.

Second year:—General history, literature, and the German language, mathematics, especially analytical geometry of planes, descriptive geometry, free-hand drawing, experimental physics, mechanics, the French language.

Studies recommended:—The English language, gymnastics, vocal music, Latin.

SCHOOL OF PRACTICAL ARCHITECTURE.

The course of studies agrees with the examinations in the Civil Service of the Grand Duchy of Hesse. The syllabus is arranged in two sections, corresponding with the examinations for higher or lower grades in the Civil Service. The courses are independent of each other.

(*a.*) Lower Course (for students who are not preparing for the Civil Service): first year:—1. Physics, acoustics, light, heat, galvanism, polarisation, optics. 2. Experimental chemistry. 3. Mineralogy and petrology. 4. Free-hand drawing, building materials, building construction (first course), ornamental drawing (first course), architectural drawing.

Second year:—Practical geometry, free-hand drawing, the mathematical theories of building construction, architectural history (first course), science of architecture, building construction (second course), ornamental drawing (second course), designing from given data (first course), streets and railways.

Third year:—Free-hand drawing, artistic perspective, architectural history (second course), building construction (third course), ornamental drawing, etc. (third course), designing from given data (second course), general instruction on mechanism.

The students are recommended to give as much attention as possible to art generally, and to aim at the higher branches, with the view of elevating their mental grasp; and by the study of the great works of ancient and modern times, and the scientific principles upon which they have been constructed, to qualify themselves for advancing in the field of intellect and professional skill.

(*b.*) Upper Course (for students who are preparing for the Civil Service examinations): first year:—Differential and integral calculus, analytical geometry of spaces, physics (acoustics, light, heat, galvanism, optics, etc.), experimental chemistry, mineralogy, and petrology, free-hand drawing, building materials building construction (first course), architectural drawing.

Second year:—Analytical mechanics, historic architecture, building specifications and cost, building construction (second course), ornamental drawing (first course), architectural designing from given data (first course), mechanical construction with details (first course).

Third year:—Practical geometry, drawing from plants (first course, to assist in designing foliage in ornamentation), mathematical theory of architecture, historic architecture (second course), building construction (second course), ornamental drawing (second course), designing from given data (second course), foundations and bridges (first course).

Fourth year:—Calculation of probabilities and method of least squares, higher geodesy, artistic perspective, the arrangement of dwellings for the people, designing from given data, bridge-building (second course), streets and railways, waterworks, general mechanism, technology, lessons selected from the course of Technical Chemistry.

The Engineering School, the School of Mechanical Construction, the School of Technical Chemistry, and the School of Architecture, are all equally exhaustive as to their courses of requirements of the instruction, and all show the most careful consideration of the student, not merely to teach him just as little as will enable him to keep his head above water, but to enlighten his mind in every way, so that he may have spirit to think for himself and to strike out new paths.

The models used in this school and in kindred institutions in most parts of the Duchy, for teaching Projection in all its branches, are exceedingly useful. A set adapted for the use of our Schools of Science, etc., and illustrating our lessons in "Projection," is in preparation. The models used for showing the various mechanical combinations are also very good. They are made principally of iron, painted and bright, and are of the average height of eighteen inches. Amongst them are the different escapements, shafts for the transmission of motion at various angles, turbines, water-wheels, various systems of spur, cog, annular, crown, face, and bevil wheels, plummer blocks, square and elliptical wheels and cams, the various modes of coupling and disengaging shafts, Watt's parallel motion, etc. All these are actual working models illustrating the lessons in the higher class text-books on Mechanism.

Turning now from schools, let us devote brief space to the description of the Trade Association of the Grand Duchy of Hesse, the organisation of which took place between the years 1836 and 1838, under the auspices of, and by grant from, the Grand Duke. The object of this association is to watch over the progress and promote the interests of trade. The management is responsible directly to the Minister of the Interior, and has so successfully worked out the plans, that the number of members, which in 1836 was 794, has now reached about 3,500, each contributing an annual subscription. The means taken by this Union to accomplish their object are various—such as (1) the publication of newspapers and periodicals devoted entirely to trade, arts, and manufactures; (2) an extensive lending library; (3) the collection of models and trade products (the models in this museum consist of illustrations of the various methods of joining timber, stone-constructions, bridges, models of heating apparatus, illustrations of brickwork, escapements for watches, English and foreign tools); (4) a collection of trade products, and (5) a fine collection of raw and manufactured trade products purchased from the Exhibition of all Nations held in London in 1851. The Association has also arranged and published an excellent set of models for teaching Projection, and some exceedingly useful sets of technical drawing copies. It also organises exhibitions of the productions of its members. Several local exhibitions have been held, and in exhibitions in other countries, notably in the Paris Exhibition of 1867, the exhibits have been such as to attract great attention, as showing the practical results of a well-applied system of Technical Education.

BUILDING CONSTRUCTION.—X.

ARCHES (*continued*)

Before, however, entering into the brick construction of the arch shown in Fig. 68, which was given in our last lesson on this subject in page 265, it is necessary to speak of the wooden supports temporarily employed in the construction of arches. These will be fully described in other lessons; still it is neces-

sary incidentally to mention them; for although they are really branches coming under the head of constructive carpentry, yet it is important that their general purpose, principles, and application should be thoroughly understood by the bricklayer and mason. The temporary wooden constructions referred to are called "centerings," and consist of an assemblage of timber beams so disposed as to form a strong frame; the convex or outer frame being of the exact form of the intrados of the arch which is about to be erected.

the arch which may take place, owing to the support being removed, may not be sudden; for if the support were at once withdrawn, the arch might settle in one part more than in another, and the whole work might in consequence give way or be permanently injured.

In Fig. 68 we find an exceedingly simple centering.

The walls A B, C D having been raised, the centering is erected. This consists of five sticks of timber, E, F, G, H, I, kept in their places by the cross-struts J K. These posts would be placed

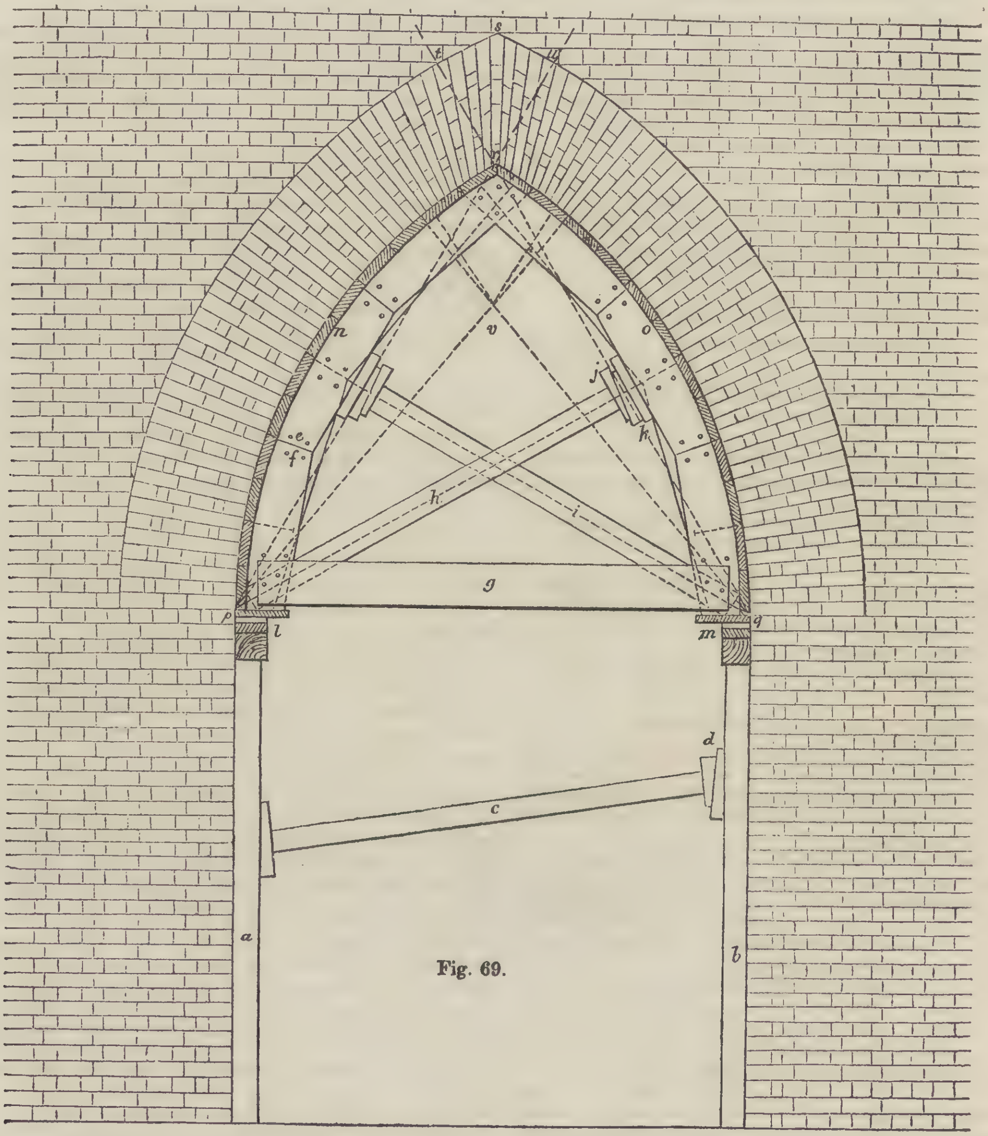


Fig. 69.

These constructions are, of course, only intended for temporary use, and therefore the following objects should be kept in view by the designer :—

1. To damage the timber as little as possible, so that it may be used again when required. Of course, this condition must yield to the necessity of the case; but in all works *proper* economy (provided it do not degenerate into a "penny wise and pound foolish" system) is an element which must never be neglected.

2. That the design of the centering must be such as to resist any strain which may cause alteration of form during the building of the arch; and

3. That arrangements should be made that the centering can be *eased* or lowered *gradually*, in order that any settlement of

at each face of the arch if it were a deep one, or even at closer distances if the arch were built over a very deep vault or passage.

Cross-wise, resting on these uprights, are laid horizontals, the ends of which, L M N O P, are shown in the illustration; and on these again planking is placed, on which the arch would be built. An important feature, however, is that mentioned under the third heading—namely, the arrangement which must be made so that the centering may be eased gradually before absolute removal.

Fig. 68 shows the most simple method of doing this. It will be seen that each support rests on two wedges mutually opposed, as Q, R, etc. Now, it will be evident that by striking each in turn, the whole of the wooden structure will sink almost

imperceptibly, and thus allow the arch to come to an equal settlement throughout, and then the whole framing may be removed.

After the preceding observations on centering, we now return to the brickwork of the subject under consideration.

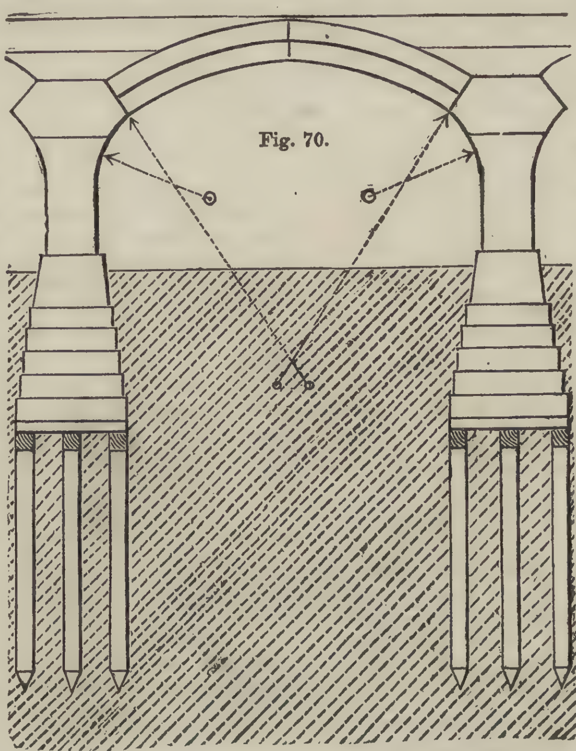


Fig. 70.

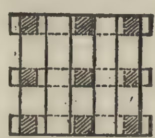


Fig. 71.

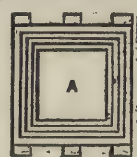


Fig. 72.

It will be seen in Fig. 68 that the greater portion of the weight of the superstructure is borne by the upper arch, which is hence called the *relieving* arch. That this is necessary will be evident when it is remembered that all the support gained from the apparently broad straight arch was that derived from the arch of the width S T, or about one brick.

The relieving arch, struck from the same centre as that to which the skew-backs of the straight arch converge, thus bears the main burden; and its purpose is further enhanced by a tension rod, U V —viz., a rod of iron passing from the intrados of the flat, to the extrados of the relieving arch, by reason of which the sinking of the former is rendered impossible, owing to its being suspended, as it were, from the latter.

Fig. 69 represents a Gothic or pointed arch, constructed of bricks. Here another very simple form of centering is shown. It will be seen that the posts *a* and *b* are placed against the piers, and are kept separate by the cross-strut *c*, the force of which may be gradually diminished by striking the wedges at *d*. On these posts rests the true centering, which, it will be seen, is formed of pieces of timber placed in the manner called "break-joint" —that is, of two thicknesses of timber, so united that the joints of the one side, *e f*, are covered by the whole wood on the other; and this mould again is supported by, first, a cross-piece, *g*, at the springing, and then by cross-struts, *h*, *i*, which can be relieved or eased by the wedges at *j* and *k*, as can also the centering by those at *l* and *m*. The several centres, or trusses, which may be required for the depth of the arch, are united by timber laid cross-wise, the ends of which are shown at *n* and *o*, etc.

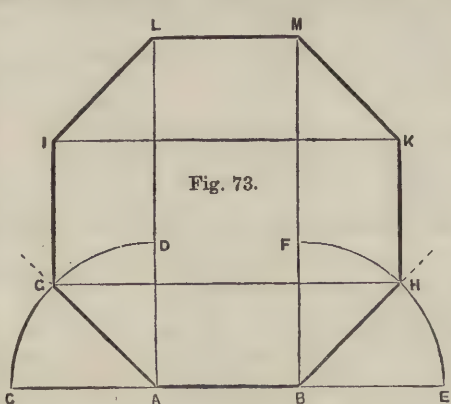


Fig. 73.

The curves of the arch are, of course, struck from the imposts, this being an equilateral arch. The intrados and extrados having therefore been drawn, divide the latter into the number of bricks required.

Now the majority of the radii are drawn to the centres from which the arcs *p*, *q* are struck; but it will be seen that if this system were continued, the entire mass of bricks forming the block *r s t u* would not be influenced by such convergence,, for the bricks would have to be cut so as to meet in the centre line, and would thus have no influence as a keystone unless a heavy weight were placed over it to keep it down, without which the pressure on each side would tend to force it upward and out of its place. When, therefore, these radii have reached about 50° on each side, and intersect in *v*, this point must be constituted a new centre, and all radii between *s t* and *s u* must be drawn to it.

DRAWING FOR MASONS.

Fig. 70 is an example of planking, brick footings, and stone piers, as adopted in the circular vaulting at the London Docks.

The foundation consists, in the first place, of nine fir piles 9 inches square, disposed as in the plan (Fig. 71). On these rest, first, three fir-sleepers, also 9 inches square, and across these fir-planking 6 inches thick, forming a platform 4 feet 10½ inches square. On this rests the mass of brickwork in five ranges, 11½ inches high, consisting of four courses (Fig. 72). The footings are 2¼ inches all round, thus making each range 4½ inches smaller across than that on which it rests. The surface of the brick foundation at A is therefore 3 feet 4½ inches.

The base of the pier, which stands on the brickwork, is of stone taken from Bramley Fall Quarry. This base is 3 feet square at the bottom, and 2 feet 4 inches at the top; the angles are, however, splayed off, and the upper surface thus becomes an octagon. The shaft, which is of granite, is octagonal, and is 2 feet wide at its lower end, but diminishes to 1 foot 10½ inches at 3 feet high. This may be said to be the springing-point of the arches. The section shows that of a four-centred arch, the centres of which are marked in the drawing.

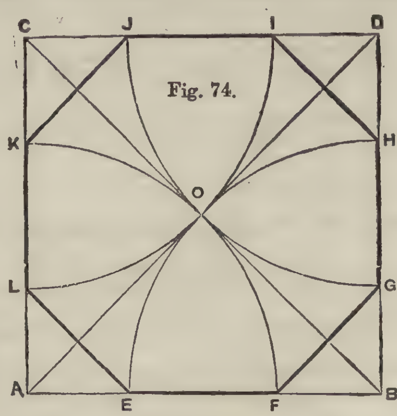


Fig. 74.

The pier widens out at the top, and is surmounted by a cap, or springing stone, also from Bramley Fall Quarry.

It has just been remarked that the upper surface of the base of the pier described above becomes an octagon when the angles at the corners are splayed off. As a useful exercise in Geometry and Linear Drawing which bears immediately on this part of our subject, we will add two problems: (1) on the construction of a regular octagon on a given line, and (2) the inscription of an octagon in a square. It is the second of these problems which is brought into practice in taking off the angles

of the block, so that, when this is done, the upper surface may present the form of a regular octagon.

To construct a regular octagon on the given line A B (Fig. 73).—Produce A B on each side. Erect perpendiculars at A and B. From A and B, with radius A B, describe the quadrants C D and E F. Bisect these quadrants, then A G and B H will be two more sides of the octagon. At H and G draw perpendiculars, G I and H K, equal to A B. Draw G H and I K. Make the perpendiculars A and B equal to G H or I K—viz., A L and B M. Draw I L, L M, and M K, which will complete the octagon.

To inscribe an octagon in the square A B D C (Fig. 74).—Draw diagonals, A D and C B, intersecting each other in O. From A, B, C, and D, with radius equal to A O, describe quadrants cutting the sides of the square in E, F, G, H, I, J, K, L. Join these points, and an octagon will be inscribed in the square.

PROJECTION.—XIII.

QUESTIONS FOR EXAMINATION (*continued*).

82. There is a solid cross, formed by a central cube of 1 inch side, on each face of which another similar cube is fixed. Give the plan and elevation when two vertical faces of the original cube are parallel to the vertical plane.

83. Draw the plan and elevation when of the two adjacent vertical sides of the original cube one is at 60° and the other at 30° to the vertical plane.

84. Project this object when resting on one angle of the base of the lowest cube, which is inclined at 30° to the horizontal plane, the diagonal being parallel to the vertical plane.

85. A cone, the base of which is 4 inches and the altitude of which is 5 inches, is penetrated by a cylinder of 2 inches diameter. The axis of the cylinder intersects that of the cone at right angles, at 1 inch from the ground. Draw plan and elevation when axis of cylinder is parallel to vertical plane.

86. Project this object when the axis of the cylinder is at 60° to the vertical plane.

87. A cone of 3 inches diameter, the height of which is $3\frac{1}{2}$, rests on a cube of 3 inches side. Give plan and elevation when sides of cube are 50° and 40° to vertical plane.

88. Project the front view of the group when the one diagonal of the base is parallel and the other at 35° to the horizontal plane.

89. There is a cube of 3 inches side, on which rests a cylinder of 2 inches diameter and 3 inches high. This supports a cone of 3 inches diameter and $2\frac{1}{2}$ inches high, the axes of all being coincident. Give the front elevation of the group, when resting in a plane inclined at 25°. The other conditions at pleasure.

90. There is a solid formed of two equal square pyramids of 2 inches base and 3 inches altitude, which are united by their bases. Draw the elevation and plan when the object rests on one of the triangular faces of one of the pyramids, the axis of the object being parallel to the vertical plane.

91. Give the projection of the object, when resting on one of the faces of one of the pyramids. The axis is at 45° to the vertical plane.

92. Draw the elevation and plan when the object rests on an *edge* of one of the pyramids, the axis being at 60° to the vertical plane.

93. Construct an isometrical scale of $\frac{1}{10}$ of an inch to the foot. Show 20 feet.

94. Draw an isometrical projection of a plane square of 2 inches side.

95. Give an isometrical projection of a pavement consisting of squares of 1 foot side. Scale, $\frac{1}{2}$ inch. Show 5 squares in width and 12 in length.

96. Draw an isometrical projection of a cube of 2 inches edge.

97. Draw the isometrical projection of a box 3 feet square and 2 feet high, made of wood 3 inches thick. Scale, 1 inch to the foot.

98. There is a block of stone, 6 feet square and 1 foot high; on this rests another, of the same height and 4 feet square; and on this again a third block, of the same height and 2 feet square, is placed, the centres of the three blocks being over each other. Give the isometrical view of the group. Scale, $\frac{1}{2}$ inch to the foot.

99. A cylinder of two inches diameter and 4 inches long lies so that its end is vertical. Give the isometrical projection.

100. There is a stool the top of which is a square of 12 inches side, the height 18 inches, and the thickness of the legs 2 inches (the other measurements at pleasure). Scale, 2 inches to a foot. Draw an isometrical view of this object.

*** It is obvious that no Key to the foregoing Exercises in Projection can be given. Each proposition must be worked out by means of drawing, and our space is too limited to do this even on a very small scale.

AGRICULTURAL CHEMISTRY.—VI.

BY CHARLES A. CAMERON, M.D., PH.D.

CHAPTER VI.—ON THE IMPROVEMENT OF SOILS.

We have shown in the last chapter that the fertility of soils is in general but little influenced by the arts of man. As a general rule, a bad soil always remains inferior to that which is naturally fertile. It is, however, possible to greatly improve the capabilities of inferior land; and, as we have seen, fertile soils go out of condition where their cultivation is not properly attended to.

Some soils are too light; they do not afford adequate mechanical support to the plant, and they do not retain sufficient moisture. On the other hand, there are clays so very adhesive, that it is almost impossible to render them sufficiently porous to allow that circulation of air and water through the soil, without which plants cannot be perfectly matured. It is evident that the act of commingling a light soil with a heavy clay would produce a mixture greatly superior to either when separate. A stiff clay may fail to produce good crops, whilst the light drifting sands—perchance not far distant—are scarcely clothed with any kind of vegetation. The combination of the two would in all probability produce a productive soil. This reasoning is very sound in theory, and sometimes it admits of being practically applied; but occasionally the operation of mixing soils is found to be a most expensive one. When the two classes of soils are close to each other, it is very probable—nay, almost certain—that their admixture could be economically effected. It is a much more common practice to improve light lands by the addition of sand or gravel to them; but it is rather rarely that stiff clays are ameliorated by the addition to them of sand, though there appears to be no good reason why such should be the case.

Bogs and peaty soils are often barren because they contain excessive amounts of organic matter; they would consequently be greatly improved by the addition of marly clays. The defective ingredients of peaty soils—alumina and lime—are abundantly present in marly clays. Light lands are often greatly improved by folding sheep upon them. The tramping of the animals consolidates the soil, and their *excreta* enriches it and renders it more coherent. Bulky fertilisers are best applied to stiff clays, and well-fermented and dense manures to light soils.

Warping soils means to manure them with mud. The annual overflowing of the Nile covers the fields of Egypt with a fine mud, which possesses wonderful fertilising properties. In some parts of England, lands adjoining tidal rivers are periodically inundated during the influx of the tide, and the excess of water allowed to flow off with the ebbing waters of the river. In this way the surface of the land acquires a coating of silt or mud, often to the depth of several inches, and even feet. Herapath found that the quantity of phosphoric acid deposited by warping on the surface of a certain field amounted to 17,000 pounds, whilst from the same field a crop of wheat only abstracted 53 pounds of that compound.

The beneficial action of quick or burnt lime on soils has been known from a very early period in the history of husbandry. The younger Pliny mentions that marl and lime were largely employed by the agriculturists of Gaul and Britain, and Theophrastus and Columella speak of lime as an article in common use amongst the farmers of their days.

Limestone consists essentially of a compound termed calcic carbonate, which is composed of carbonic dioxide, oxygen, and the metal calcium. When heated very intensely, the carbonic dioxide flies off in a gaseous form, and the oxygen and calcium remain as a white earth, termed calcic oxide, or calcic anhydride. When water is poured on calcic anhydride (quick or

caustic lime), the two substances unite and form calcic hydride (slaked lime, formerly termed hydrate of lime). During the slaking of lime heat is evolved, and the hard stone crumbles into a fine powder. If an excess of water be used, a semi-liquid results, termed cream or milk of lime, according to its consistency.

In the soil lime acts chemically and physically, and it also contributes directly to the nutrition of plants. As a mere mechanical agent, it has proved most useful in rendering stiff clays less tenacious, and more porous and pervious. Many heavy clays, which can only be properly cultivated by great labour and expense, might be rendered friable, and easily workable, by a liberal application of lime. Dense, adhesive clays do not readily admit the permeation of air through them; therefore any mechanical agent—such, for example, as lime—which renders them more open, indirectly contributes to their chemical improvement, because the active circulation of air throughout the soil produces abundance of plant-food, as we have shown in a previous chapter.

As lime, though not so dense as heavy clay, is more compact than sands, the latter are improved by a dressing of marl—a substance very rich in lime. In the case of clays and sands, no apprehension of injury from over-liming need be apprehended, provided that the lime be applied chiefly in the form of marl or chalk; for enormous quantities of quicklime act corrosively upon vegetables and their seeds. The best wheat soils in Middlesex contain 10 per cent. of calcic carbonate, and in many of the most fertile grass-lands in Ireland more than 20 per cent. of this substance exists; whilst some of the soils of Somersetshire—famous for their cheese-producing capabilities—contain about 70 per cent. of lime compounds. In the use of lime as a mechanical agent the chief point to consider is, Will it render the soil too light? In the case of green crops there is little danger of the soil being too light; but when oats and other cereals are cultivated, it sometimes happens that over-doses of lime are applied. In such cases—even if the soil be old lea or grass-land—the plants may braird satisfactorily, but they will hardly produce seeds, and will generally perish about June. The cereals require a moderately stiff soil to sustain their slender roots, and if such support be denied they rarely vegetate vigorously. Land rendered too porous by over-liming is improved by growing turnips on it, and allowing sheep to feed upon the crop in the field. The soil may also be consolidated by means of heavy rollers passed over it. It is a curious fact, that land, injuriously affected by over-liming, may yet be in want of lime. This arises from the circumstance that lime sinks very rapidly from the upper 4 or 5 inches of surface-soil; and although the whole soil may have been rendered too loose by former calcareous applications, yet the part of it from which the nutriment of the crop is chiefly derived may be deficient in lime. In cases of this kind, lime should be applied in the form of a heavy compost. Road-scrapings are often found a useful application to land suffering from the physical effect of over-liming, but which is in actual want of calcareous matter.

The chemical action of lime upon soils is most important. Burnt lime, chalk, and marl combine with, and render innocuous, various hurtful acids which occasionally occur in soils, but more especially in undrained lands. Farmers well know that lime *sweetens* (to use their own term) their lands, and that it produces on meadows and pastures sweet and nutritious herbage.

Quicklime acts chemically upon some of the rocky parts of soils, and hastens their disintegration or decay; in this way lime liberates a portion of the fertilising matter contained in the coarser portion of the soils.

Every fertile soil contains a large amount of organic matter, formed chiefly from plants and parts of vegetables more or less decayed. During the decomposition of the organic matter (*humus*, or mould) its constituents enter into new combinations, and ultimately pass into their original mineral condition of carbonic dioxide, water, and ammonia, and earthy and saline matters. The perfect decay of organic matter only takes place when air is present; and hence the more porous a soil is, the more quickly does its *humus* decay, because there is an abundant circulation of air in the soil. Quicklime also hastens the decomposition of organic matters, converting their nitrogen (combined with a portion of their oxygen) into nitric anhydride, which, uniting with lime, produces calcic nitrate (nitrate of lime)—a valuable source of nitrogen to plants. When soils contain an excessive proportion of organic matter, they are greatly benefited by an abundant application of lime. A single "dressing" of lime to an unproductive bog or peaty moss often produces a fine and spontaneous crop of white clover.

Limestone, gravel, marls, and shell and coral sand owe their efficacy almost wholly to the calcic carbonate which they contain. They neutralise the sour liquids in undrained and boggy soils, and they supply lime to the crops. Shell and coral sands are well adapted to poor heathy lands; limestone-gravel is an excellent agent in the reclamation of bogs. Marls and chalk have a wide application, and may be always used wherever the soil is deficient in lime. Limestone containing a small proportion of magnesia may be employed in agriculture; but dolomite, or magnesian limestone, should not be used, for when burned and slaked its hydrate forms a hard mass instead of a powder.

Quicklime exposed to the air absorbs—but very slowly—the atmospheric carbonic dioxide, and in part becomes calcic carbonate—a compound which on the whole is not nearly so useful in agriculture as burnt lime. The sooner lime is used after it comes from the kiln the better; and its conversion into calcic carbonate should be impeded by preserving it in large heaps. A thin layer of quicklime soon loses its caustic properties.

The quantity of lime applied as a prime "dressing" per statute acre varies; the longer the land has been without a liming, the greater is the quantity of lime which it requires. For medium and stiff soils 150 bushels are probably the minimum, and 300 bushels the maximum, quantity with which the best results may be effected. In the case of light lands 70 or 80 bushels will in general suffice. Wet land requires more lime to produce a given effect than is necessary in the case of wet soils; and here we have another instance of the many economical results of drainage. When the soil has been well limed it will, as a rule, be benefited by a moderate application of the earth once during each rotation of crops.

The processes of "paring" and "burning," at one time considered to be in almost every case injurious, are now admitted by scientific agriculturists to be often very useful, when properly carried out. Good soils seldom contain more than 10 per cent. of organic matter; but bogs often include 95 per cent. (excluding water) of partially decomposed vegetable matter, and only 5 per cent. of mineral matter. When bogs do not furnish fuel (turf or peat), or when that part of them which is generally used as fuel has been exhausted, their excess of organic matter is sometimes best got rid of by burning it. In general the combustion should be allowed to extend downwards to the depth of from 3 to 7 or 8 feet. The less mineral matter contained in the peat, the greater is the quantity necessary to be burned in order to obtain a sufficient quantity of ashes to mix with the unburned turf. Marshy land, and soils containing mosses and other weeds and coarse herbage, are improved by burning their surface; the weeds and their seeds are thereby destroyed, and their ashes increase the fertility of the soil. Burning is sometimes one of four processes employed in the reclamation of bogs; the others being drainage, liming, and the application of sand or clay.

A common defect of clays is their extreme plasticity and adhesiveness. Their particles lie so closely together that air and water cannot freely circulate amongst them. If we subjected a piece of clay to intense heat, it would assume a glassy or slag-like condition; but if we heated it moderately, it would only become a dry, porous, and friable mass. Now, by burning heaps of weed, cinders, or coal-dust on clays (selecting very dry weather for the operation), we can greatly improve their texture, and increase their productive capacity. After such an operation the air gains access to the interior of the soil, and prepares from its rocky particles the fine fertilising powder which, as we have already stated, is the chief source of the ash, or inorganic constituents, of plants.

TECHNICAL DRAWING.—XIX.

DRAWING FOR MACHINISTS AND ENGINEERS.

MECHANICAL DRAWING.

Fig. 202 is a drawing of a simple fly-wheel of a winch.

Draw the circles A and B for the outer and inner edge of the rim.

Divide the circle B into six equal parts, and draw the diameters C D, E H, G F, or radii C, E, F, D, H, G.

Next draw the circles I and J, and also the circle *i*, the edge of the boss being bevelled.

A portion of the inner circle, representing the end of the shaft, is then to be slightly flattened, and the key by which the wheel is fastened is to be added.

To find the points from which the arcs are to start from the straight lines, describe a circle passing through N O, cutting the sides of the other five arms in the required points.

Similarly, the arms at their base are united by an arc, which, in a subject as small as this, may be struck with any convenient

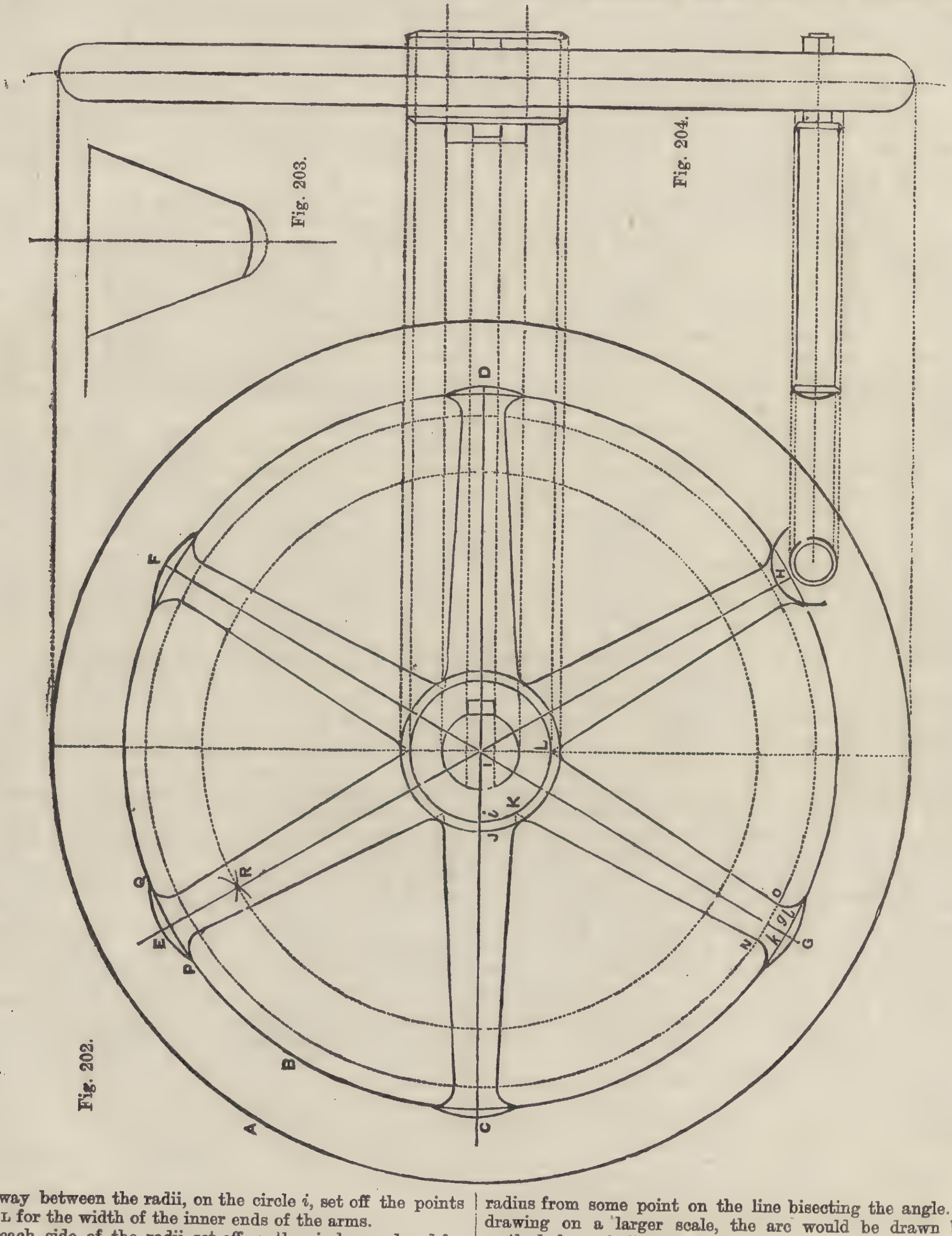


Fig. 203.

Fig. 204.

Fig. 202.

Midway between the radii, on the circle *i*, set off the points K and L for the width of the inner ends of the arms.

On each side of the radii set off on the circle B, *g k*, *g l* for the width of the arms at their outer end.

Draw K *k* and L *l*, and repeat the process on each of the radii.

The arms do not, however, meet the rim in a sharp point, but the straight lines are joined to the circle by means of a small arc, shown at N and O. These arcs are to be drawn as already shown in Figs. 180 and 181.

radius from some point on the line bisecting the angle. In a drawing on a larger scale, the arc would be drawn by the method shown in Fig. 200.

These curves should not again form angles at the points where they meet the straight lines, which would be the case if drawn too flat, as in Fig. 203. The arcs should be so drawn that the curve merges imperceptibly into the straight lines, as shown by the dotted portion.

From one of the points in which the radii cut the circle B, as E, set off the distance E P, E Q.

From P and Q set off the length P Q on the radii, and from P and Q, with radius P Q, describe arcs cutting each other in E, and from this the arc P Q may be struck, representing the curve formed by the arm meeting the rim, which is rounded off to a semi-circular section at its inner and outer edges, as will be seen in the edge elevation (Fig. 204). This last is projected from Fig. 202, and should be drawn upon a centre line, whilst the centre line for the handle is drawn from the centre of the end of the handle.

Fig. 205 is a geometrical elevation of a V-threaded screw, as rendered in mechanical drawings in the general course of business. This is entirely a conventional method, generally used in the elevation of a cylinder such as would remain if the thread of the screw were turned completely off. This is called the *inner* cylinder. Again, the perpendiculars B and C give the elevation of a cylinder which would just contain the screw; this is called the *outer* cylinder.

Now set off on the central perpendicular a number of divisions equal to half the width of the thread—viz., F, G, H, I, J, etc.

Through these points draw oblique parallel lines, taking care that their inclination is not too much to be inconsistent with the pitch of the screw, of which more will be said in another lesson.

These oblique lines are to extend alternately across the inner

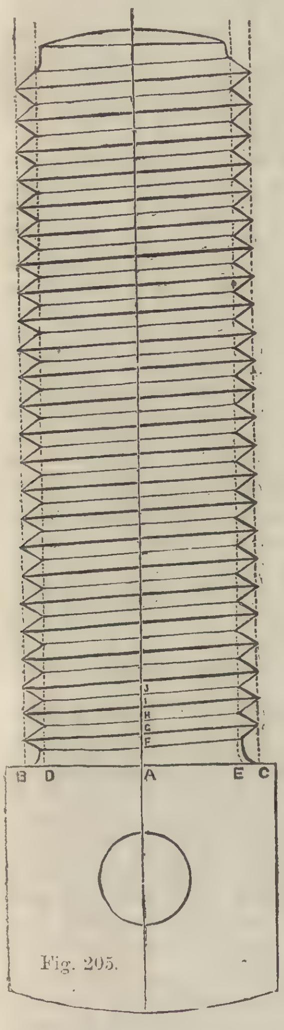


Fig. 205.

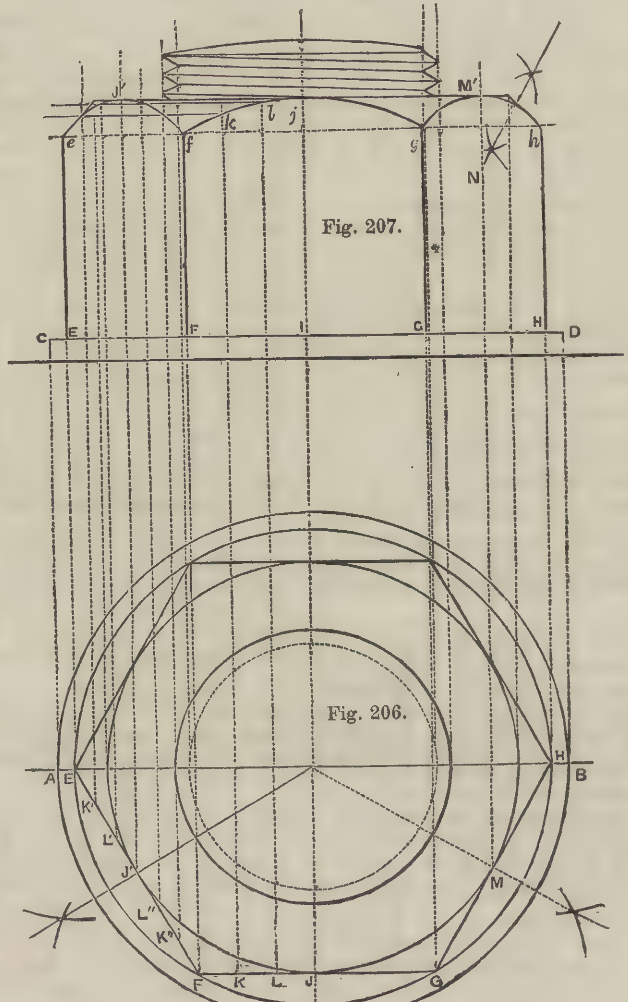


Fig. 207.

Fig. 206.

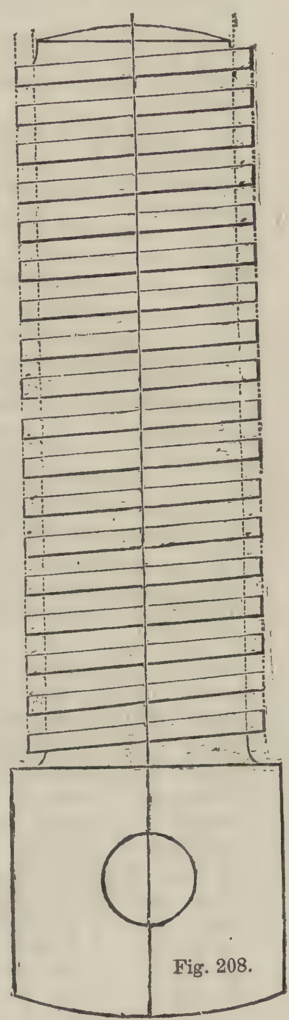


Fig. 208.

Mechanical Drawing, for, in reality, the line which forms the thread of a screw is one which, in ascending, winds round a cylinder, and is termed the *helix*. The rapid method shown in this figure is, however, found so very useful that it is thought desirable to make the student acquainted with it in this place, in order that he may be able to draw subjects in which the screw may be introduced; but the correct method of projecting screws will be worked out further on.

Draw a central perpendicular, and at the base construct the rectangle representing the head of the screw, the curve at the bottom being struck from a point on the centre line.

On each side of A set off half the diameter of the screw—viz., A B and A C, and draw perpendiculars from these points.

Next set off from A, A D and A E, and erect perpendiculars from these points also. The perpendiculars D and E will give and the outer cylinders, and the angle of the thread is formed by joining their extremities.

The mode of starting the screw at the head and of terminating it at the end, etc., will be understood from the example without further remarks.

Figs. 206, 207.—The subject of this study is a hexagonal nut, showing also the end of the screw and washer.

Having drawn the plan (Fig. 206), project the circular washer from the diameter A B, and draw the horizontal C D (Fig. 207) at the proper height.

It will be seen that the nut is a portion of a hexagonal prism. The full working out of the projection of prisms has been given in the lessons in "Projection."

Next project the perpendiculars E *e*, F *f*, G *g*, and H *h* from the points E, F, G, and H on the plan.

From I (Fig. 207), with radius I j, describe the arc $f\,g$, which will give the curved edge of the face of the nut, which is parallel with the vertical plane of projection.

This arc, of course, is the same on each of the faces; but does not appear so on the other two which stand at angles to the plane of projection. It is therefore necessary to find points through which to draw the curve as it appears.

Divide one-half of the line F G in the plan—viz., F J—into any number of equal parts, as K, L, etc., and from these points erect perpendiculars, cutting the arc $f\,j$ in k and l.

Now divide the side represented by E F in the plan into double the number of parts marked on F J—viz., K′, L′, J′, L″, K″, and from these points raise perpendiculars.

Draw horizontals from j, l, k, cutting the perpendiculars, and through these intersections the curve is to be traced.

In common practice it is usual, however, to draw this curve with the compasses, which may be executed in the following manner:—

Draw a perpendicular from M in the plan to cut a horizontal drawn at j in M′; then find a centre for a circle to pass through g, M′, and h—viz., N. Then from N, with radius N g, an arc used as a rapidly-executed substitute for the curve $e\,j'\,f$ can be drawn.

The screw is to be drawn as shown in the last figure.

Fig. 208 is a conventional representation of a square-threaded screw, as commonly used in practice. It must, however, be distinctly understood that this method, like that shown in Fig. 205, is only admissible in drawings on a small scale.

The method of drawing this figure is, in the first instance, precisely similar to that employed in the V-threaded screw; the oblique lines, however, are all drawn across the outer cylinder, and the alternate pairs united.

SEATS OF INDUSTRY.—V.

By H. R. Fox Bourne.

MANCHESTER AND ITS SUBURBS: THEIR MINOR INDUSTRIES.

To the cotton manufacture of the Manchester district all its other trades are subordinate, yet many of these are very important, and conduce greatly to the welfare of the locality and the whole country.

Chief of these are the hardware trades by which suitable machinery is supplied for the working-up of cotton. Manchester, indeed, vies with Birmingham in the more polished and delicate branches of iron manufacture. In its neighbourhood are some of the largest and most skilful machine-shops in the world, and the demand for tools, which has caused great tool-making establishments to be there set up, has at length made Manchester a centre of iron-trade with far-off regions and in all varieties of iron-ware. Manchester had, in 1860, 48 iron foundries and 63 machinists' shops, giving employment to about 12,000 workpeople, while some 60,000 persons were employed in its 95 cotton mills, and it had, besides, 13 silk mills, with about 2,000 labourers, and 16 small-ware mills, giving employment to nearly as many. Those figures fairly indicate the relative value of the principal industries, not only of Manchester itself, but of all the district round about. Everywhere cotton is chief, but silk and wool are also worked up, and in greater proportion as we pass from Manchester in the direction of the woollen province of Yorkshire or the silken province of Derbyshire; and everywhere engineers are at work constructing mills and tools for the textile manufactures.

No better representative of this iron industry can be found than the Fairbairn Engineering Company in Ancoats. The veteran engineer whose name it bears was, indeed, to some extent the father of the whole trade. "When I first entered this city," he said of Manchester in 1816, "the whole of the machinery was executed by hand. There were neither planing, slotting, nor shaping machines, and, with the exception of very imperfect lathes and a few drills, the preparatory operations of construction were effected entirely by the hands of the workmen. Now everything is done by machine-tools, with a degree of accuracy which the unaided hand could never accomplish. The automaton, or self-acting machine-tool, has within itself an almost creative power—in fact, so great are its powers of adaptation that there is no operation of the human hand that it does not imitate." In working out that change, Sir William Fairbairn himself did much. He had mastered his trade in London and elsewhere before—twenty-four years old—he settled in Manchester as a working millwright. In 1817 he entered into partnership with a shopmate, James Lillie, and they began a small business of their own. Paying 12s. a week for a small shed, in which they set up a lathe of their own construction, they did various odd jobs until more important work came in their way. They had not long to wait for that. A large commission for mill-work from Adam Murray, a great cotton-spinner, was so well executed that other commissions became plentiful. Sir W. Fairbairn led the way in many of the improvements in mill-work and machine-making that have been effected during the last half century; and where he was not himself the inventor, he succeeded in giving full effect to the inventions of others. He came to be not only the chief engineer and machinist for the Manchester cotton industries, but a great iron-worker for all the world. He was one of the first to develop iron ship-building in 1829, and there are few branches of the iron trade in which he was not engaged. His help to the cotton-spinners, however, was sufficiently important. "In 1815," he said, a few years ago, "the shafts of our cotton-mills were moving at 40 or 50 revolutions a minute, whereas at the present day we have as many as 300 and 350. The same number of revolutions are applicable, and now in use, for lace and silk. The extensive employment of wrought-iron for shafts and the slide-lathe has given wonderful facilities to the production of shafts for increased velocities, with reduced friction, by the transmission of great power through a comparatively small section. In some of the more recent mills of my construction we have shafts only two and a-half inches in diameter conveying the power of a 40-horse engine." It was by that sort of work—by making strong, yet light and slender iron do the duty formerly assigned to clumsy wood, and by carefully fitting all the parts together, so as to receive as much power and as little waste as possible—that Sir W. Fairbairn helped to bring about a revolution in all varieties of mill-work. The large establishment which still bears his name now comprises five great divisions. There is a foundry and forge, provided with steam-hammers, for wrought-iron. There is a boiler-yard, with machinery for rivet-making, shearing, and punching, and a bridge-yard, with similar appliances; there is a millwrights' department, stocked with blacksmiths' forges, turning, planing, and fitting shops; and there is an engine department, able to produce steam-engines of every size and variety required.

Establishments like that of the Fairbairn Engineering Company abound in Manchester and all the adjoining districts. Some adhere more closely to Sir W. Fairbairn's original project, and confine themselves to millwrights' work. Others help the cotton-trade by other kinds of metal-handling. Here, a great factory is devoted to the construction of weavers' tools. There, the work done is chiefly limited to the making of steam-engines. There, again, it may be, only the rough iron-work for railways is done. But everywhere the grand motive is the same—the increasing of facilities for bringing to the Manchester district its great stores of cotton-fibre; for turning it, when there, into cloth; and then for conveying it most promptly and easily to other parts.

The extension of the silk-trade to the Manchester district owes its origin to the old habit of blending silk and cotton in one fabric. Macclesfield, seventeen miles south of Manchester, is the chief resort of silk-workers in this neighbourhood. Here the trade has been of very long standing. Although benefited in one direction, it has been damaged in another, by the spread of cotton-manufacture. The Macclesfield silk-trade was at its height between 1808 and 1825. In 1819 the first silk-mill in Manchester was set up by Mr. Vernon Royle, and in that year it was reckoned that the town contained about 1,000 weavers of mixed silk and cotton goods and 50 workers in pure silk. In 1832 it gave employment, in pure and mixed manufacture, to about 3,600 hands, while the total number of men and women concerned in the trade throughout the Manchester district was nearly 70,000.

The number of other trades, more or less dependent on the cotton-manufacture, that have grown up in this great province, are legion. "Amongst the textile fabrics," says Mr. Harland, "are those, single and mixed, of woollens, worsted, stuff,

flannel, etc., including blankets; of linen, alone, or mixed with cotton, wool, or silk; velvets, table-cloths, and damasks; counterpanes and quilts; nankeens, jeans, etc.; crapes and bombazines, muslins and mousselines-de-laines, shawls and mantles—in short, every kind and variety of textile fabric is manufactured in Manchester. Amongst more miscellaneous manufactures are those of hats and caps, umbrellas and parasols, india-rubber, gutta-percha, and other waterproof and air-proof fabrics. In copper and brass are various manufactures, especially of rollers for calico-printers, boilers, steps, etc.; in tin, all kinds of wares, including boxes and cases for enclosing goods for hot climates; paper for writing, printing, and packing. In short—including the trades and handicrafts whose produce or productions are in demand everywhere, and those which may be termed the agencies between producer and consumer—there are from six to seven hundred varieties of occupation in Manchester, supplying all the numerous wants of a high material civilisation." Of all that, cotton is the chief cause; but the cotton manufacture could not have attained its vast proportions in this district, but for the proximity of coal and iron with which to work it, and the presence of that perseverance and enterprise which characterises the population as a whole, and has enabled it to send out from its ranks so many men of eminence. Inventors and discoverers—a great number—have arisen in Manchester and its far-reaching suburbs; notable merchants and manufacturers in yet greater number; and not a few skilful statesmen, with Sir Robert Peel at their head.

The eminent Scotch engineer who established the Fairbairn Engineering Company was born in 1789. He was elected President of the British Association in 1860, created a baronet in 1869, and died in 1874. He wrote some valuable works on mills and mill-work, and "Iron, its History and Manufacture."

THE ELECTRIC TELEGRAPH.—V.

By J. M. Wigner, B.A.

OTHER FAULTS—CONTACT—DEFECTIVE EARTH—LIGHTNING GUARDS—MODE OF RENDERING SIGNALS INTELLIGIBLE—SINGLE NEEDLE INSTRUMENT—CODE.

Besides the faults to which we referred in our last paper, there are a few others of common occurrence, the effects of which must be explained in order that we may be able at once to detect them. Perhaps the most common of these is "contact" between two of the wires connecting any two stations. This is sometimes produced by damp weather enabling the current to escape along the surface of the insulators, and is then known as "weather contact." More frequently, however, it arises from one of the wires becoming so slack as to touch against another, or else from some electrical connection being accidentally made between them.

A fault of this kind is very easily recognised. The current leaves the transmitting station, deflecting the needle there as

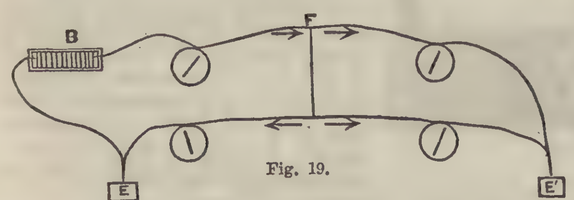


Fig. 19.

usual. At the fault, however (F, Fig. 19), three courses are open for it, and it accordingly divides between them. One portion continues to travel along its own wire, and deflects the needle at the receiving station, but less powerfully than usual, since much of the current has escaped another way; a second portion passes by the place of contact, and returns along the second wire to the sending station, deflecting there the needle of the other circuit, but in the contrary direction; the third portion travels along the same wire to the receiving station, deflecting the second needle there. These effects are more or less modified by the various resistances of the different circuits, still they are so obvious as at once to indicate the nature of the fault.

Another cause of failure is "defective earth" at the receiving station. The communication with the earth-plate is in this case either broken or defective, and a portion of the current accordingly returns by other wires, deflecting their needles in the reverse direction to those in the regular circuit. This fault is liable to be mistaken for contact.

The only other fault we shall refer to is demagnetisation of the needles or other injury to the instrument. The most common cause of such failure is that the lightning has struck the line in some part, and passing along it has injured the instrument. The fact of frequent injuries arising from this cause directed the attention of electricians to the discovery of some simple means of obviating the danger, and many efficient expedients have been introduced.

Lightning in its effects is found closely to resemble frictional

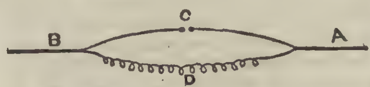


Fig. 20.

electricity. If we have two pieces of wire, A and B (Fig. 20), connected together by a spiral of fine wire, D, and also having connected to them two pieces of wire ending in small balls (C) which nearly touch one another, any galvanic current will pass through the spiral, since it cannot leap across the break between the two balls, however small it be. Frictional electricity would, however, at once take the more direct course, and leap over the small interval at C. This, then, is the principle on which most lightning conductors act, and Fig. 21, which represents Breguet's Lightning Discharger, shows us one mode in which this principle is put into practice.

Two plates of metal cut at the ends into teeth resembling those of an ordinary saw are fixed to a wall, so close to one another that their teeth almost touch. The line-wire, L, is connected with the one of these seen on the left, and the current passes along the plate to the piece of metal *a*, and thence along a piece of fine wire, contained in a glass tube, to the screw *b* and the instrument. Another wire, J, leads from the right-hand plate to the earth, so that if the lightning strikes the line the electric fluid will dart from the points and travel on to the earth by this wire. Should this wire fail to carry off all the current, the thin wire in the glass tube is fused by it, and thus it is prevented entering the instrument-room and injuring the instruments there. The fine wire can, of course, be very easily replaced. The object of the handle seen attached to one plate is that during a storm it can, if required, be turned so as to afford a direct communication between the two plates, and thus cut the instruments for the time entirely out of the circuit. In some forms of lightning protector a thin wire, like that enclosed in the glass tube, is depended upon alone for protection, since any quantity of electricity like that produced by a flash of lightning would instantly melt this wire, and thus save the instruments. In the protector which we have explained protection is afforded in both ways, and it is therefore doubly safe. Many other forms of lightning discharger are employed, but nearly all act in a similar way, and we need not, therefore, stay to explain the peculiar construction of each.

We have thus seen the way in which the electric current is generated, the manner in which it is conducted from place to place, and the precautions which have to be taken to prevent its escape. We have also seen the nature of the more common interruptions in any electric circuit, and we must therefore pass on to that which is perhaps the most important point of all—the manner in which an electric current may be made to produce intelligible signals at a distant place, and the construction of the instruments that are employed for this purpose.

An electric current is capable of producing many different effects, as we have already seen in our "Lessons on Electricity" in The Popular Educator. It will convert a bar of soft iron into a magnet, or cause a compass needle to point in a different direction; it can be made to decompose water and various chemical substances, or to render a piece of fine wire red-hot, and to produce many other results. Many of these effects are capable of being employed as a means of transmitting our thoughts and messages, and in fact there are few of them that have not so been employed at different times and by various

inventors. The number of instruments that have been introduced is, therefore, very large indeed, and there are many varieties which are still in constant use.

The three effects of the current which have been by far most generally used in telegraphy are—

1. Its power of reversing a magnetised needle.
2. Its power of converting a bar of iron into a magnet.
3. Its power of decomposing various chemical substances.

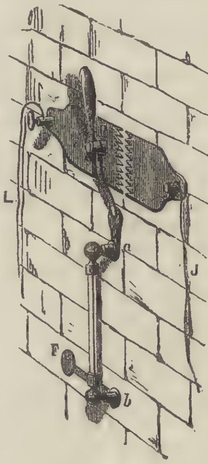


Fig. 21.

Perhaps the first is the most simple effect of all, and "needle instruments" which depend upon it are so extremely common that we will take these first, and endeavour fully to understand their construction and action.

The broad principle on which they act was discovered by Oersted, and is simply this—that if an electric current be made to pass along a wire placed near a magnetised needle, that needle, instead of pointing to the north, will point to one side of it; and if the current be made to pass along the wire in the reverse direction, the needle will point to the other side of the north. If, then, we have such a needle at the receiving station, and possess the means of sending at pleasure a positive or a negative current, we can cause this needle to be deflected to the right or left at pleasure, and from these two signals we can form a code by which any letter in the alphabet can be sent.

In the needle instrument, as in all other kinds of instruments used in telegraphy for the transmission of messages, three distinct parts are necessary: these are (1) the transmitting instrument, (2) the receiving apparatus, and (3) the alarum.

It might be thought that the last-named part is indispensable, but this is not the case, since the click of the needle might call the attention of the clerk in charge to the fact, that a message was coming. This is, however, very unsatisfactory, as an important message might be seriously delayed by the clerk not hearing this; an alarum is therefore always employed. It consists of an apparatus by which the current is made to ring a bell in a manner that will hereafter be described. It would, however, be very undesirable that this bell should continue to ring all the time that the message is being received, and an arrangement is therefore made by which it may at pleasure be cut out of the circuit, a more direct path being then provided for the current.

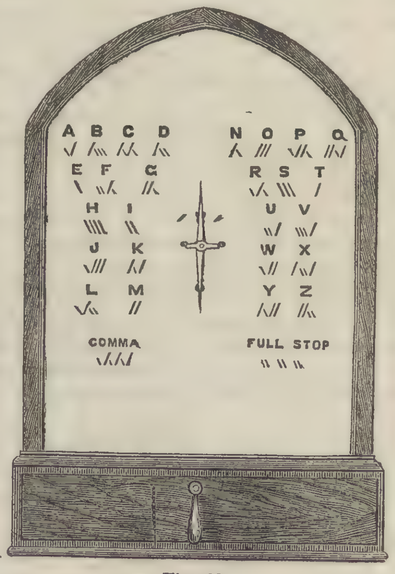


Fig. 22.

The usual plan is for the circuit, under ordinary circumstances, to be completed through the alarum. As soon as this rings, the clerk, by means of a switch, turns the current from the alarum to the instrument, and receives the message, taking care, when he has received it, to alter the switch again. The alarum is often put in the same case as the instrument, but it is essentially a distinct thing.

The general appearance of the single needle instrument is shown in Fig. 22. In the centre of the dial-plate is seen the needle, the play of which is limited by means of two small pins placed one on each side. The handle in the lower part of the instrument is for the purpose of moving the transmitting apparatus, which is so arranged that when this handle is inclined to the right a current is transmitted along the line in such a direction that all the needles in the circuit are likewise deflected to the right, and when this handle is moved to the left a current is sent in the reverse direction, so that the needles are all deflected to the left. When a motion of the needle in either direction is spoken of, it should be remembered that it is the upper end of the needle that we mean.

The mechanism in the interior of the instrument, by which the current may be sent at will in either direction, will be explained in our next paper. We will here assume that we have the power of sending at pleasure either a positive or a negative current. All the needles along the line of wire will accordingly act simultaneously, and be deflected in the same direction. We possess, then, two distinct signals—viz., an inclination of the needle to the left or a similar inclination to the right. The lower end of the needle is so weighted that as soon as the current ceases it shall return to its original vertical position.

From these two signs, then, we have to construct an alphabet, and this is not a very difficult task, since we can give two or more consecutive beats in either direction, or in alternate directions. No letter is found to require more than four such beats, and by carefully arranging the letters so that those most commonly employed are represented by the simplest signs, we are enabled to send messages with an average of a little more than two inclinations for each letter. A trifling pause is made between each letter, and a somewhat longer one between the words; but after a little practice it is easy to read off messages, even if some of these are omitted.

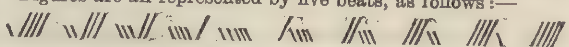
The code of signals is, of course, purely arbitrary; a standard one has, however, been settled on, and is now almost universally adopted, since great practical inconvenience is found to arise from the use of several independent codes. That originally introduced for the single needle instrument has now almost entirely given way to a universal one, based on that employed with the "Morse" instrument. This latter is seen on the face of the instrument shown in Fig. 22, and will easily be understood from that.

E and T being the letters in most general use, are represented by single beats of the needle to the left and right respectively. A, I, M, and N each require two beats, while all the rest of the alphabet require three or four.

By a few examples we shall very easily learn the meanings of the marks on the instrument face. A is indicated by a beat to the left, immediately followed by one to the right; B by one beat to the right and three to the left. Other letters are more complicated than these—F, for instance, requiring two to the left, one to the right, and then one more to the left. The signs appear at first to be somewhat difficult; but a little practice soon removes this, and enables the operator to receive or transmit messages with considerable speed.

In addition to these signs for letters there are several others which are frequently required, and hence are included in the code. When a word or message is understood, the receiver acknowledges by a single beat to the right; if, on the other hand, he cannot decipher the movements of the needle, he gives a beat to the left, to signify "not understand."

Figures are all represented by five beats, as follows:—



1 2 3 4 5 6 7 8 9 0

and as the signs succeed each other in a regular course they are easily remembered.

The signs of punctuation are represented each by six distinct beats. Those for the comma and full stop are given on the dial-plate, and will be seen to be equivalent to the letters A A A and I I I respectively. A note of interrogation (?) is represented by the signs for U D; inverted commas (" "), by those for A F; a hyphen (-), by B A; an apostrophe ('), by W G; and parentheses ( ), by K K. In each of these cases the beats succeed one another without any pause, and the letters are merely given as an aid to memory.

VEGETABLE COMMERCIAL PRODUCTS.—X.

INDUSTRIAL AND MEDICINAL PLANTS.

I.—TEXTILE PLANTS, OR PLANTS FROM WHICH WE DERIVE CLOTHING AND CORDAGE.

We are indebted to the vegetable kingdom for clothing as well as food. At what time man first discovered the means of forming articles of clothing from the fibre of plants is not known, but the practice is very ancient. It was understood in the time of the Pharaohs, more than 1,600 years before Christ. Flax is thus alluded to in Genesis xli. 42:—"And Pharaoh took off his ring from his hand, and put it upon Joseph's hand, and arrayed him in vestures of fine linen." It is not improbable that flax was cultivated even in pre-historic periods. It formed both the garments and grave-clothes of the inhabitants of ancient Egypt; for the microscope shows that the cere-cloth which envelopes the Egyptian mummies consists of the fibre of flax. We, therefore, place it first on our list of textile plants, as the one of which we have the oldest historic record.

LEAVES AND BUDS OF THE FLAX PLANT.

Common Flax (*Linum usitatissimum*, L.; natural order, *Linaceæ*).—This plant is a smooth fibrous-rooted annual, about two feet high, with sessile, alternate, lanceolate leaves and terminal blue flowers, in corymbose panicles. Ovary globular, five-celled, each cell containing two smooth, oval, brown, and glossy seeds.

Flax has a very remarkable geographical range, thriving in the temperate, sub-tropical, and even tropical regions. It is not only cultivated in the United Kingdom, but in every part of Europe, in Egypt, and in India. Formerly every rural family in England cultivated as much flax as was required for domestic purposes; now the spinning-wheel has been superseded, and both linen and cotton goods are manufactured by steam machinery in the greatest abundance, in every variety of pattern, and with much less time and labour.

To obtain the fibrous or woody tissue of flax, the plants, after flowering, are first pulled up, dried in the sun, collected, and then soaked in water to destroy their green outer bark. This process is called water-retting, the word "retting" being a corruption of rotting. The tough fibres of the stalks are thus set free, are again dried, and then scutched, or beaten with a heavy wooden instrument, which completes their separation. After this they are heckled, or drawn through the combing apparatus, next bleached, and, lastly, handed over to the spinner.

THE HAIRY SEED OF THE COTTON PLANT.

From flax so prepared, coarse linen fabrics are manufactured; but the flax must be heckled several times through much finer combs to render it fit for the manufacture of fine linen, lawn, or lace. Tow consists of the rough and broken fibres detached from the skeins during the combing process. Linen when scraped is termed lint, in which form it is very valuable to the surgeon as a dressing for wounds.

About 1,816,669 cwt. of flax, dressed and undressed, were imported into the United Kingdom in 1868, chiefly from Russia, Egypt, Turkey, Italy, Belgium, and Holland. We also raise flax largely ourselves, especially in Ireland, where it is one of the staple commodities.

Hemp (*Cannabis sativa*, L.; natural order, *Urticaceæ*).—The hemp-plant is a tall, roughish annual, with a stem from five to ten feet in height, and digitate leaves, with five to seven linear-lanceolate, coarsely-toothed leaflets. The flowers are green and inconspicuous, in compound racemes or panicles, and monœcious, that is, the stamens and pistils are in separate flowers on the same plant. The seed is produced in great abundance, and is used for feeding small birds. The fibres of the stem are much longer and stronger than those of flax, and when separated and prepared (in a manner very similar to that adopted with flax, and already described) constitute the hemp of commerce, from which sail-cloth, sacking, and every variety of cordage are manufactured.

The hemp-plant is a native of Persia and of the northern parts of India, whence it has been introduced into Europe, where it is now extensively cultivated, especially in Russia. Like flax, hemp has a very extensive geographical range, growing in almost any country and climate. It thrives admirably in North America and in Africa, and is found both in a wild and cultivated state from Northern Russia to tropical India.

When growing in warm countries the value of the hemp is much diminished, and another quality is developed—it becomes powerfully narcotic, and its leaves, flowers, and stem become covered with a peculiar resinous secretion called *churrus* in India. By the Arabs this resin is called *hashash;* and during the Crusades, men intoxicated purposely with it, called *hashasheens*, used to rush into the camp of the Christians to murder and destroy, whence our word *assassin* is derived. Hemp is employed in other forms besides churrus as a narcotic. The whole herb, resinous exudation included, is dried and smoked under the name of *gunyah* or *bhang*, when the larger leaves and capsules only are employed. The Hindoos of British India, and the Bushmen of Southern Africa, smoke these preparations in rude pipes, as we do cigars and tobacco. These pipes are about three inches in length, and are usually made out of the tusk or canine tooth of some animal, perforated quite through, leaving only the enamel. The general effects of tropical hemp on the system, when smoked, are alleviation of pain, great increase of the appetite, and much mental cheerfulness.

From experiments made with churrus, it would seem that the fakeers and other religious devotees of India are indebted to it for their ability to perform some of their wonderful feats. One of these experiments is thus described by Dr. O'Shaughnessy:*—"At two p.m. a grain of the resin of hemp was given to a rheumatic patient; at four p.m. he was very talkative, sang, called loudly for an extra supply of food, and declared himself in perfect health; at six p.m. he was asleep; at eight p.m. insensible, but breathing with perfect regularity, his pulse and skin natural, and the pupils freely contractile on the approach of light. Happening by chance to lift up the patient's arm, to my astonishment I found it remained in the posture in which I placed it. It required but a very brief examination of the limbs to find that the patient had, by the influence of this narcotic, been thrown into that strange and most extraordinary of all nervous conditions, genuine *catalepsy*. We raised him to a sitting posture, and placed his arms and limbs in every imaginable attitude. A waxen figure could not be more pliant or more stationary in each position, no matter how contrary to the natural influence of gravity on the part: to all impressions he was meanwhile almost insensible." Similar results were obtained from experiments on animals. As soon as the influence of the drug ceases, the patient recovers, without having received any injury from its effects.

SECTION OF SEED OF THE COTTON PLANT.

The narcotic hemp of warm climates was, owing to its peculiarities, thought to be another species, but it is now known only to be a variety, and is distinguished as *Cannabis sativa*, variety, *Indica*.

The imports of hemp into the United Kingdom in 1868 were 1,042,320 cwt., chiefly from Russia, Hungary, Northern Italy, the Philippine Islands, and British India. The best Hungarian hemp comes from the district of Peterwardein, under the name of Sclavonian hemp. From Italy we receive, in small quantities, a remarkably fine variety, raised by spade culture, called "Italian garden hemp."

* "Popular Economic Botany," by T. C. Archer, page 153.

In addition to sail-cloths and cordage, a coarse brown paper is made from hemp. Oakum consists of tarry hemp, procured by untwisting old worn-out ship ropes, and is a most invaluable substance to the ship's carpenter, who uses it as stuffing with which to stop any leakage in the vessel during the course of the voyage. Seams of timber-built ships are also caulked with oakum.

Cotton Wool (the woolly covering of the seeds of several species of *Gossypium*; natural order, *Malvaceæ*).—Much uncertainty prevails amongst the best botanists as to the number of species of *Gossypium* which furnish cotton. Linnæus has described five, Lamarck eight, Wildenow ten, and De Candolle admits of thirteen. The cotton of commerce, which consists of the hairs attached to the seeds, and is therefore cellular tissue, appears to be derived mainly from three species, designated as the cotton herb (*Gossypium herbaceum*, L.), the cotton shrub (*Gossypium Indicum*), and the cotton tree (*Gossypium arboreum*).

1. Cotton Herb (*Gossypium herbaceum*, L.).—The greatest amount of cotton is derived from this species, which is the best known and most widely spread. It is an annual, and cultivated in the United States, India, China, and many other countries. It grows from three to four feet in height, having sub-cordate, three to five-lobed, alternate leaves, and pale-yellow flowers resembling those of the mallow; the stamens are monadelphous, or united into one bundle by their filaments, and the pistil has a three-celled ovary.

After the plant has done flowering, a capsule is formed which is surrounded by the calycine and involucral leaves. This capsule grows to about the size of a walnut in its husk, turns brown as it ripens, and then opens, displaying in its three-celled interior a snow-white or yellow down enveloping each of the three seeds lying in each cell; altogether, nine cotton balls may be collected from each capsule, each ball with its enclosed seed being about the size of an ordinary grape.

Chinese Nankin cotton is manufactured from a variety of this plant. The yellowish-brown colour of the nankin is not artificially produced by dyeing, but is the natural colour of the cotton from which it is fabricated.

2. The Cotton Shrub (*Gossypium Indicum*, Lamarck).—The cotton shrub is cultivated in India. It closely resembles the former plant in many respects, but it grows from eight to twelve feet high; its flowers change from white to red, and its capsules are ovoid. The cotton shrub is cultivated in all countries where the cotton herb is found. In the West Indies this plant lives from two to three years, in India and Egypt from six to ten; and where the climate is excessively hot, it is usually very long-lived.

3. The Cotton Tree (*Gossypium arboreum*).—The cotton tree inhabits India, China, Egypt, the coast of Africa, and some places in America. It grows from fifteen to twenty feet high, and its flowers are red. It yields a variety of cotton of a very fine, soft, silky nature, which is used by the Hindoos for making turbans.

The cotton plant is usually cultivated in fields, and treated as an annual. It is grown from seed which is placed in the ground in holes, sufficiently wide apart to allow for the growth of the plant. The plants are carefully tended until they flower, which is usually eighty days from the time of sowing. The flowers, which are handsome, either yellow or red, and not unlike those of the garden hollyhock, are succeeded by capsules, which, when ripe, open, and the cotton-covered seeds in their interior are immediately removed by the cultivator before the wind is able to scatter them. These cotton seeds are then sent to a mill, where by means of a peculiar apparatus called a *gin*, the cotton is separated from them; they are then either kept for sowing again, or as material for the manufacture of oil, and oil-cake for cattle.

Cotton comes to this country in packages called bales. The word *bale* is applicable to any kind of goods packed in cloth and corded with rope. The average weight of each bale is 336 lb.

In 1866, 4,098,601 bales of cotton, weighing 12,295,803 cwt., were imported into the United Kingdom. The value of this cotton in the raw state was £77,521,406, and its value, when manufactured into cotton fabrics, £232,564,218. Of these fabrics we exported to the value of £60,865,022, the remainder being retained for home consumption. In 1868 the quantity of raw cotton imported was 11,857,893 cwt. The substitution of the power-loom for the hand-loom has caused such an amount of prosperity to the cotton trade, that it is now one of the most important branches of our foreign commerce.

In business, foreign cotton is separated into the following varieties:—

North American or United States Cotton.—This is produced in the states of Georgia, South Carolina, Alabama, Mississippi, and Louisiana. The best American cotton, which is, in fact, the best known in the market, is the celebrated Sea-island cotton, which grows on a row of islands situated along the coast of Georgia. The principal ports for the exportation of United States cotton are Charleston, New Orleans, Mobile, and Savannah.

South American Cotton.—This comes into the market from the Brazils, Guiana, Columbia, Venezuela, New Granada, and Peru. Almost all the West India islands, too, produce cotton, and indeed of a superior quality, preferable even to that obtained from the Brazils.

African Cotton.—Excellent cotton is received from the French island of Bourbon; Egyptian cotton has also greatly improved in quality recently, because the crops have been raised from American seed. The best African cotton is, however, grown in Algeria, and is remarkable for the beauty of its colour, the fineness of its silk, the care taken in harvesting the crop, and the good condition in which it appears in the market. The long silk cotton of Algeria partakes at the same time of the character of the long silk staple of Georgia, and the short cottons of Egypt, and approaches in quality the finest Louisiana variety. Algeria is capable—if the necessary encouragement is given—of producing the finest cotton in the world.

East Indian Cotton.—This is very inferior to the North American, although British India, next to America, furnishes the largest quantity. The silk is very short, and not adapted to European machinery, which is framed for working the finer American long cotton. This cotton is raised chiefly for exportation to China. Recently a better staple has been produced in India from American seed, and already a considerable quantity has been exported to England. East Indian cotton comes in little bales, very strongly compressed and corded, which are carried on the backs of camels, or on wagons, to the Ganges, and there received into boats with capacious interiors; these descend the river, and take the cargo to European ships. The East Indian sorts known in commerce are the Bengal, Madras, Bombay, Surat, Siam, and Manilla cottons.

Levant Cotton.—This includes all the cotton which is received from ports in European and Asiatic Turkey, as well as from the Morea and the Archipelago. Like that from British India, it is of inferior quality. The principal sorts are the Smyrnian, Syrian, Cyprian, Macedonian, and Persian cottons. Most of the last is consumed in Persia, excepting some small quantities, which go to Russia *vià* Astracan.

OPTICAL INSTRUMENTS.—IV.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLES FOR THE PRESBYOPIC.

In the normal or emmetropic eye the recession of the near-point commences about the tenth year, and progresses regularly with increasing age. At forty, it lies about 8 inches; at fifty, at from 11 to 12 inches, and so on; and no inconvenience is experienced from this recession till about the age of forty or forty-five. This change in the near-point is met with in all eyes, being also found in the healthy myopic and in the hypermetropic eye, and is due to anomalies of accommodation; while hypermetropia, myopia, and astigmatism are referable to anomalies of refraction (see Figs. 6 to 11, page 160). The question will be asked, When are we to consider an eye presbyopic? Donders has established an arbitrary standard by which he considers we should regard presbyopia to have commenced when the near-point is found to have receded farther than 8 inches. The hypermetropic eye is considered to become presbyopic so soon as, while using glasses which neutralise the hypermetropia, the near-point lies farther from the eye than 8 inches. This standard also holds good in regard to myopic eyes, when the distance of the near-point amounts to more than 8 inches, and it follows that only to slight degrees of myopia can presbyopia in the ordinary sense of the word belong;

where $M = \frac{1}{8}$ it is almost impossible, even with total loss of the power of accommodation. In slight degrees of myopia, presbyopia occurs much later than in the emmetropic eye. Herein the myopic (of $\frac{1}{10}$ to $\frac{1}{14}$) find a compensation for what they lose, in respect to vision of distant objects, and the advantage is not slight, to find that they can, up to the age of sixty or seventy, dispense with spectacles for the observance of such objects as come immediately under their eyes—an advantage never enjoyed by the emmetropic.

Some persons flatter themselves that they enjoy this privilege when at fifty-five the near-point lies at only from 8 to 10 inches, and spectacles have not been found necessary; such persons are proud of their sharp sight, and consider themselves a lucky exception to the laws of decay. Any suggestion as to their being near-sighted is answered in the negative, by a self-complacent smile. On trying them with Snellen's distance-test, placed at 20 feet off, XX, XXX, or even XL, are not recognised, L or LX being the first easily distinguished, and not until they try concave glasses of $\frac{1}{50}$ or $\frac{1}{36}$ can they recognise XXX or XX. Such are consequently myopic. On inquiry, it will generally be found that the parents presented the same peculiarities, when an inference may be drawn that the myopia is hereditary. But the far-point also begins to recede somewhat in the normal eye above the age of fifty; so that it then becomes slightly hypermetropic (distant vision being improved by convex glasses), which at seventy or eighty may $= \frac{1}{24}$ (that is, the patient can see distinctly at a distance with a convex glass of 24 inches focus). In such a case, the hypermetropia, which at first is only acquired (*H. acquisita*), may afterwards become absolute; so that the person is not only unable to accommodate for divergent, but even for parallel rays.

We must be careful not to confound that weakness of sight termed amblyopia with presbyopia, which might easily occur, as an amblyopic person also cannot see small objects distinctly, and convex lenses (by affording him larger retinal images) improve his vision. If the patient cannot with a suitable lens distinguish No. 1 of Jäger at 8 inches distance, but only 4 or 6, or if he is obliged to hold the object nearer to his eye than is warranted by its size, then he is amblyopic. It may be laid down as a practical rule that the nearer we can approximate, by means of convex glasses, the vision and range of accommodation of a presbyopic eye to that of a normal one, the less is the impairment due to amblyopia, and *vice versâ*.

How are we to determine the degree of presbyopia, and correct the deficit of accommodative power?

According to the old method, usually practised in opticians' shops, the patient is tested by the "tryers," "sight-suiters," or "trial case," which consists of a series of carefully worked convex lenses mounted in pairs in tortoiseshell spectacle-fronts, which are clamped together at one end by a pivot that holds them in a box, which also forms a handle to be held by the patient, while each front in turn is placed before his eyes to find which focus enables him to read moderate-sized type at ordinary reading distance, the probable whereabouts of the power required being arrived at by some such guide as the following:—

At **40** years of age convex lenses of **36** inches focal length will *commonly* be required; at **45**, **30**; at **50**, **24**; at **55**, **20**; at **58**, **18**; at **60**, **16**; at **65**, **14**; at **70**, **12**; at **75**, **10**; at **80**, **9**; at **85**, **8**; at **90**, **7**; at **100**, **6**—the three last deep lenses, 8, 7, 6, being rarely required, except for "couched eyes."

After the patient has been once fitted it usually only becomes a matter of increasing the power of his spectacles by the glasses next higher in focal range, on his complaining that those he is then using are not sufficiently strong.

The convex trial case includes the above-named series of 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 24, 30, 36, and also 48 inches foci, the last being sagaciously and judiciously termed "preservers." Such a rule-of-thumb method must, however, soon give place to the more exact system established in recent years by Continental oculists.

According to Donders, the degree of presbyopia may be readily found, thus:—

$$\text{If } p > 8'' = 8 + n, \text{ presbyopia. Pr.} = \frac{1}{8+n} - \frac{1}{8};$$

which simply means, we must deduct the (arbitrary) presbyopic near-point (8 inches) from the absolute presbyopic near-point determined by trial.

If we find a patient's near-point lies at 12 inches, the formula would stand thus—

$$\tfrac{1}{12} - \tfrac{1}{8} = -\tfrac{1}{24}, \text{ Pr.} = -\tfrac{1}{24};$$

or supposing it to lie at 16 inches, it is

$$\tfrac{1}{16} - \tfrac{1}{8} = -\tfrac{1}{16}, \text{ Pr.} = \tfrac{1}{16}.$$

This also gives the focus of the convex lens, which would bring the near-point back again to (the arbitrary standard for the near-point) 8 inches.

In the first case, the convex required would be 24 inches; in the second case, 16 inches.

In each case the *difference* between the two fractions expresses the deficit of accommodation the patient labours under. In the former case he would find himself, for distinct vision at 8 inches, *minus* such an amount of accommodation as is equivalent to a 24-inch convex lens, in the latter case to a 16-inch convex lens; consequently, if to the first we artificially supplied a 24-inch convex, and to the second a 16-inch convex, in each case we should correct his presbyopia; and provided that the patient exerts *all* his natural accommodation ($\frac{1}{24}$ and $\frac{1}{16}$ respectively), he would be able to read, etc., at 8 inches. Few persons, however, could sustain such a strain on the ciliary muscles for any length of time without fatigue (asthenopia); but as few persons wish to work for any length of time at so close a distance as 8 inches, a more convenient distance, such as 10, 11, or 12 inches, will answer without overtaxing the natural power of accommodation. The result of theory must, however, always be checked by trial, for it will often be found that strain may be avoided by supplying a weaker lens than the above formula indicates.

The object to be attained in supplying a presbyopic person usually with spectacles should be to reinforce his defective accommodation by convex lenses neither so strong as to supersede his own remaining natural accommodation, nor so weak as to tax it further than it admits of.

For such corrective trials a set of lenses of known focal length, in pairs, is required, together with a spectacle-frame, in which such lenses can be readily fitted and changed. Jäger's frame is the best, as the rings for supporting the glasses are movable, to admit of their distance being regulated, so that the patient can look through the centre of both glasses; and, further, it allows of the centre of the pupils being noted. The set employed on the Continent comprises 28 pairs of bi-convex lenses of 2, $2\frac{1}{4}$, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 22, 24, 28, 36, 40, 48, 60, 72, and 100 inches positive focal length, and 28 pair of bi-concave lenses of corresponding negative focal length, together with a set of glass prisms with refracting angles of 3°, 4°, 5°, 6°, 7°, 8°, 9°, 10°, 12°, 14°, 16°, 18°. These usually correspond to the Prussian inch, which differs but little from the English inch, but is less than the Parisian inch. In practice a reduction will rarely be necessary; but it should be remembered that, as a large number of lenses supplied to opticians are of French manufacture, while the English scale is usually employed for measuring focal length, etc., the English inch is only equal to about 0·94 of the Parisian inch. It is evident care must be taken that the lenses used in the optician's trial box also correspond to the French scale, and that his optometer is graduated to the same measure, unless he uses lenses worked to the English scale, when of course the English system must be adopted for "tryers" and optometer. As it is well known that at first, while the amount of presbyopic disturbance is but slight, glasses of $\frac{1}{60}$ are usually sufficient, and also that in proportion as the time of life advances, and the range of accommodation steadily diminishes, stronger and stronger glasses are required, it was not unnatural that opticians and oculists should arrange glasses according to the time of life at which, on an average, they became necessary; but as eyes differ too much to make age alone the criterion in the choice of spectacles, with some amount of justice this old custom has been ridiculed; but as far as emmetropic eyes are concerned, the diminution of the range of accommodation being as a rule regular, the time of life may in general be taken as a guide, if the many circumstances which modify the indications furnished by the time of life be not overlooked.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—V.

To inscribe four equal circles in a circle, each touching two others and the containing circle (Fig. 48).

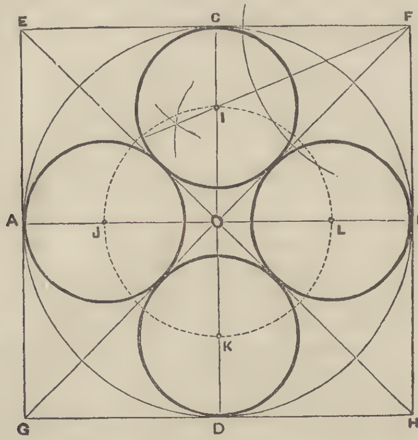


Fig. 48.

Draw the diameters A B and C D at right angles to each other.

From A, B, C, D, with radius of the circle, describe arcs cutting each other in E, F, G, H.

Join these points, and a square will be described about the circle.

Draw the diagonals E H and G F.

Bisect the angle C F O, and produce the bisecting line until it cuts C D in I.

From O, with radius O I, describe a circle cutting the lines A B and C D in J, K, and L.

From these centres, with radius I C, describe the four required circles.

To inscribe seven equal circles in a circle (Fig. 49).

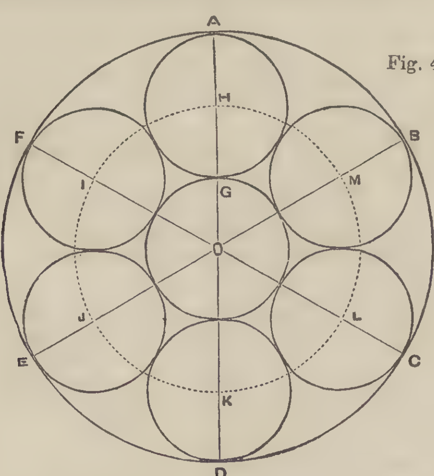


Fig. 49.

Around the circumference of the circle set off the radius, thus dividing it into six equal parts in the points A, B, C, D, E, F, and draw the radii.

Divide one of the radii, as O A, into three equal parts—viz., O G, G H, H A.

From O, with radius O G, describe the central circle.

From O, with radius O H, describe a circle which, cutting the radii, will give the points I, J, K, L, M.

From these points, with radius O G, describe the six circles, each of which will touch the central circle, two others, and the containing circle.

Similarly, a circle O G being given, to draw six equal circles to touch it and each other, divide the circumference of the given circle into six equal parts. Draw radii and produce them. From G set off G H, equal to G O. From O, with radius O H, describe a circle which, cutting the produced radii, will give, with H, the centres I, J, K, L, M of the six circles.

Within a circle to inscribe any number of equal circles, each touching two others and the containing circle (Fig. 50).

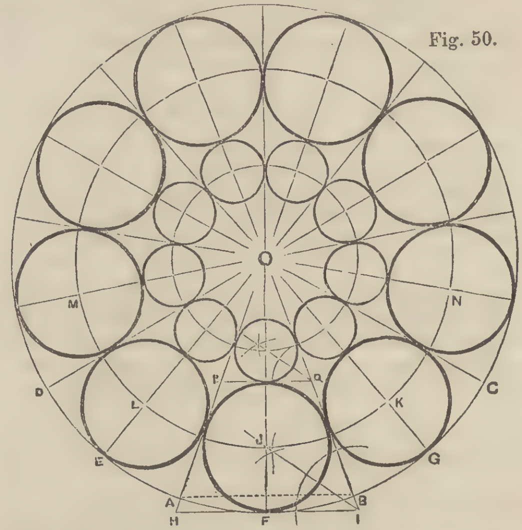


Fig. 50.

Divide the circle into equal sectors, corresponding to the required number of circles—viz., D A, A B, B C, etc., and bisect the sectors by the lines E, F, G, etc.

Produce any two of the radii, as A and B, and draw the tangent H I parallel to A B.

Bisect one of the angles at the base of the isosceles triangle thus formed, and produce the bisecting line until it cuts O F in J.

From O, with radius O J, describe a circle cutting each of the lines which bisect the sectors in L, M, N, K, etc.

From these points, with radius J F, describe the required circles.

By drawing P Q parallel to A B, and bisecting the angle at the base of the triangle, the centre for another circle may be found; and by continuing the process as before, another series of circles may be drawn.

Application of the division of a circle in drawing a rack and trundle (Fig. 51).

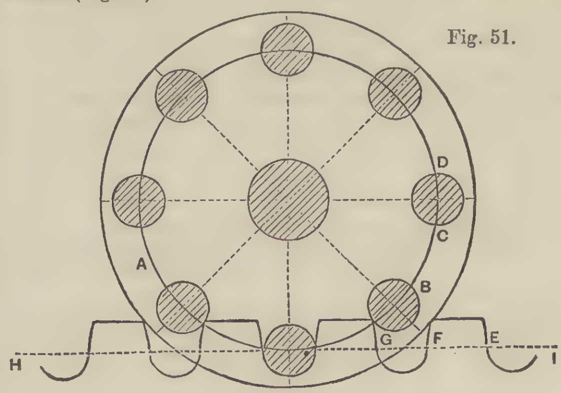


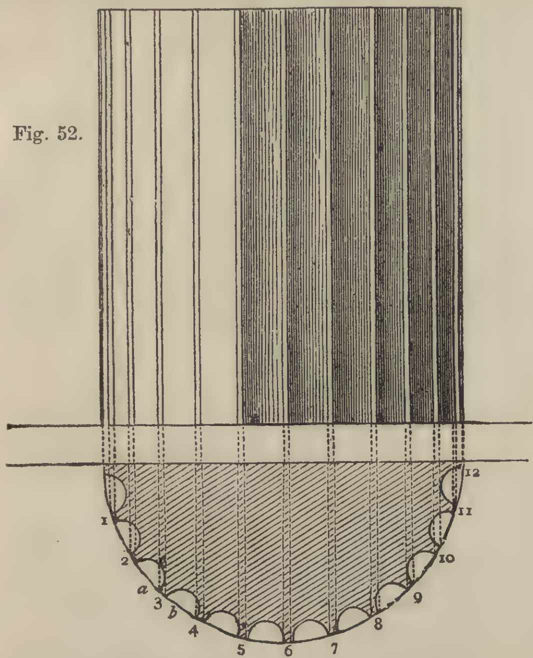
Fig. 51.

The circle A, on which the centres of the circles representing sections of the bars (or teeth of the trundle) are placed, is called the *pitch circle;* and the line on which are the points of contact between the teeth of the rack and those of the wheel, is called the *pitch line.*

The pitch circle must be divided into parts equal to the given number of teeth, and spaces, B C, C D, etc., must be set off on the pitch circle, and similar lengths, E F (= B C), F G (= C D), etc., must be set off on the pitch line H I. The rest of the construction will be readily understood on reference to the figure.

Numerous studies in this branch of the subject will be given in the series of lessons on "Technical Drawing."

Fig. 52.



The above (Fig. 52) is an example of the division of circles in drawing the plan and elevation of a column, and is introduced here in order to impress on students the necessity of acquiring the utmost accuracy in division of spaces.

The circle forming the boundary of the plan is to be divided into a number of parts, corresponding to the required number of flutes—viz., 1, 2, 3, etc.; half the width of the fillets is then to be set off on each side of these divisions, as *a*, *b*, etc., and semicircles drawn from the centres of the remaining spaces.

The elevation of the column is projected by drawing perpendiculars from the various points in the plan.

For full details in the construction of elevations, plans, etc., see lessons in "Projection."

To divide a circle into any number of equal parts, having the same area (Fig. 53).

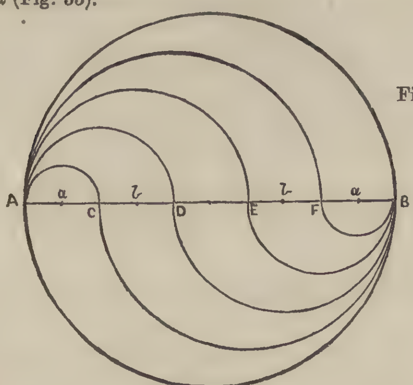


Fig. 53.

Divide the diameter A B into the required number of equal parts, A C, C D, D E, E F, F B.

From points *a*, *a*, midway between A C and F B, describe semicircles, F B and A C.

From point E, describe the semicircle C B.

From D, describe the semicircle F A.

From *b* and *b*, midway between C D and E F, draw the semicircles E A and D B.

From C and F, draw the semicircles D A and E B, which will complete the figure.

To divide a given circle into a given number of concentric rings and central circle having the same area (Fig. 54).

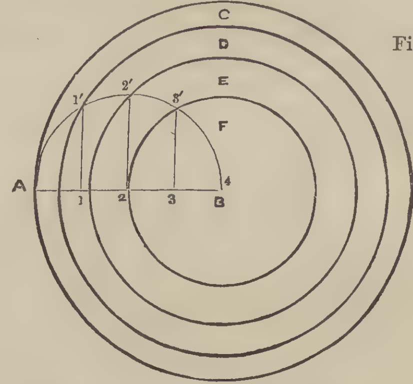


Fig. 54.

Draw a radius A B, and on it describe a semicircle.

Divide the radius A B into the number of equal parts corresponding with the number of rings, etc., required.

From the points of division, 1, 2, 3, raise perpendiculars cutting the semicircle in 1′, 2′, 3′.

Then from the point B as centre, with the radii B 1′, B 2′, B 3′, draw circles passing through the points 1′, 2′, 3′.

The concentric circles passing through these points divide the area of a given circle into three concentric rings, C, D, E, and an inner circle, F, all having an equal area.

The following figure is given as a study of geometrical drawing, showing an ellipse in which the curve is to be drawn by hand. Further studies, also to be drawn by hand, of a semi-elliptical arch, and an elliptical figure formed by arcs of circles, will be given in the next lesson.

To draw an ellipse, the diameters A B *and* C D *being given* (Fig. 55).

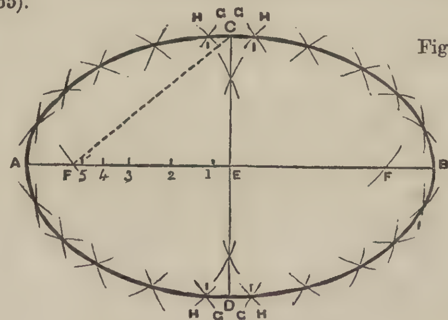


Fig. 55.

Place the diameters A B and C D at right angles to each other, intersecting in E.

Find the foci F and F from C with radius equal to E A.

Between E and F, mark off any number of points, as 1, 2, 3, 4, 5. (It is advisable that these points should be nearer together as they approach F.)

From F, F, with radius 1 B, describe the arcs G, G, G, G.

From F, F, with radius 1 A, describe the arcs H, H, H, H.

The arcs H, H, H, H will intersect the arcs G, G, G, G in I, I, I, I, and these will be four points in the curve.

Proceed to strike arcs from F F, first with 2 B, and then with 2 A; and these intersecting will give four more points.

When arcs have been struck with the lengths from all the points to A and B, the curve of the ellipse must be traced by hand through the intersections.

CHEMISTRY APPLIED TO THE ARTS.—VI.

BY GEORGE GLADSTONE, F.C.S.

TANNING.

HIDES, in common with other animal substances, are liable to putrefaction; and this action cannot readily be stopped, except by a process of drying, which renders the skin hard and stiff,

or by that of tanning, in which the softness and pliancy, which are attributes of so much importance, can be retained. Hides and skins—the former term being applied to those of the heavier and larger animals, such as the rhinoceros, buffalo, ox, etc., and the latter to the smaller and lighter, such as the calf, sheep, goat, etc.—are in tanning converted into leather; an operation due to the affinity of tannic acid for the gelatine and albumen as well as the animal membrane contained in the raw article, which leads to the formation of a new compound that is not decomposed by the action of the atmosphere.

The skin of all animals consists of two distinct parts—the epidermis, or scarf-skin, which forms a very thin layer in the exterior surface, and the cutis, or true skin, which lies below. It is with the latter that the tanner has to do. This is a fibrous substance largely composed of gelatine, whereas the other is of a horny character, and is not acted upon by the tannin. The affinity of the true skin for tannic acid may be easily tested, by making an aqueous solution of the latter, and then inserting in it a piece of skin of an ascertained weight, which will take it all up; and the quantity of acid which had been dissolved in the water may then be calculated, by finding the increase in weight which the skin has attained during the operation.

The raw articles are received into the tan-yard in very various conditions. The ox-hides and sheep-skins from the shambles are just in the state in which they came off the slaughtered animals; those received from abroad have, however, undergone some process to keep them from decomposition in the meantime; they are generally either dried, in which case they have become almost rigid, or they are pickled in salt, in which case they retain much of their moistness and pliancy. The East India and Cape supplies are usually dry, and have the hair remaining upon them; the wet, salted hides mostly come from South America.

Before describing the course of treatment to which they are subjected, something must be said of the various substances generally used as sources of tannin. The most familiar of these is oak bark, having until recently been much more exclusively used than now. It still continues to be the only important article containing tannic acid which is obtained in any quantity in this country, though the bark and leaves of most trees contain more or less of this principle. The bark of young trees contains the largest per-centage, and the quantity is greater in spring than at other seasons; but in this country neither of these considerations has much weight, the bark being of secondary importance to the timber, which improves with age, and is best when felled in the summer or autumn. These circumstances serve to account for the great variations in the quality of different parcels of bark, and show the importance of determining by chemical means the quantity of tannin they contain, which cannot be even approximately arrived at by the most experienced judges from the mere appearance of the samples. Birch and willow bark are sometimes used in this country, but the former much more generally in Russia; the agreeable and very permanent odour that distinguishes Russia leather being due to a peculiar oil contained in the bark of the birch.

The warmer climates supply a number of vegetable productions rich in tannin, that are constantly attracting increased attention, and are destined to enter into still more general use, as the home supply of oak bark would not keep pace with the increase of the demand, were the tanner dependent upon it alone. From the shores of the Mediterranean two very important articles are received—sumach and valonia. The former consists of the leaves of the tree so called, which are dried and ground up; the latter is the cup of a particular species of oak that grows extensively in Greece and Turkey, and which is remarkable for its very large acorns.

From the tropics are obtained dividivi, myrobalans, and catechu, which are all rich in tannin. The first of these is the fruit-pod of a tree which grows in tropical South America; the second is the dried fruit of one that is common in India; and the last named (of which there are several varieties, known under the names of terra Japonica, cutch, and gambier), consists of the inspissated juice of certain trees which grow principally in the East Indies. These last are extremely rich in the important elements, being weight for weight about five times as effective in tanning as oak bark.

Of late years the acacia trees, which abound in great variety in Australia, have been found to yield barks which are valuable in tanning, and considerable quantities of leather are now made with the aid of this material.

The value of these different articles to the tanner is not, however, to be measured exactly by the proportion of tannin which they contain. The trade always looks for what is called "bloom" upon the leather, and those substances which produce this effect best are consequently specially appreciated. The want of this quality in the different kinds of catechu detracts from the value which their richness in the tanning properties would otherwise assure to them; while oak bark, valonia, and dividivi are distinguished for the beautiful bloom which they impart. It is also worthy of note that some substances, which are themselves rich in tannic acid, are of no actual value for the manufacture of leather; for though they will produce the chemical action necessary for this purpose, it is found in practice that the leather made with them is liable to decomposition, so that it is wanting in its most important characteristic. Oak-galls, and all other excrescences which are not natural vegetable growths, have this defect; and infusions of them are also very liable to another disadvantage—viz., a readiness to ferment, which results in the conversion of the tannic into gallic acid, the effect of which will be described presently.

The usual processes for converting hides or skins into leather must now be described. If green hides (*i.e.*, those fresh from the slaughterhouse) are to be operated upon, the first thing to be done is to cleanse them, by taking off all the particles of flesh, etc., which may be adhering to them; and then, if they are not to be used at once, they must be pickled in salt to keep them sweet. Foreign hides, which have necessarily been either dried or salted, need a great deal of soaking in water to render them soft and porous; so that a large supply of water is an essential requisite in a tan-yard; and the water should be soft, as the earthy ingredients in hard waters are apt to form insoluble compounds with the fatty matters in the skin, and so prevent the action of the tan.

The next step is to take off the epidermis, and the hair with it. This is commonly done by liming, for which purpose the skins are steeped in vats containing a solution of quicklime in water, from three days to three weeks, according to the nature of the article operated upon, the heaviest hides requiring the longest time. During this process the skins are handled, or turned over periodically, in order to keep the liquor stirred, and so prevent any unevenness of action upon them. The hides are then scraped with a long two-handled knife upon a beam; the beam, as it is called, being a sloping bench with a curved surface, over which the hide is stretched during this operation. The sharp edge of the knife removes the epidermis and the hair at the same time. If the hide is then found to be uneven in thickness, it is turned over, and the inner side is subjected to a scraping and rubbing down until all inequalities are removed.

The preparatory liming has unavoidably caused some of those insoluble compounds which have been already referred to as the result of using hard water; and these must be got rid of before commencing the actual tanning process. For this purpose a "bate," or solution of dogs' dung, is used, in which the hides are steeped for a week or ten days. The "bate" contains an ammoniacal chloride, the chlorine of which combines with the lime, forming a soluble compound that can be easily removed by washing.

There are other modes of preparing for taking off the hair which have their advantages, especially in rendering the bating unnecessary. It may be done by producing a fermentation, for which purpose some milk, or a mixture of meal and water, is very effective. Another mode is technically called "sweating;" it is produced by piling the hides one over the other in a pit, when a considerable heat will be generated, and putrefaction will commence. This will be evidenced by the presence of an ammoniacal odour which will be evolved; and care must then be taken to check the process immediately the hair has become loose, as a continuance of the action would prove deleterious to the quality of the hides. Exposing them to the action of steam in a steam-chest will produce the same loosening effect upon the epidermis, and it is not attended with the risk of injury, which is one of the objections against the sweating process.

The hair having been removed, and the bating (if necessary)

having been accomplished, the next step is to prepare the hide to receive the tan as readily as possible. This is called "raising," the result being the distension of the cellular tissue of the skin, which facilitates the subsequent action of the tan. It may be done either by immersing the hides in a very weak aqueous solution of sulphuric acid, or of spent tan—the latter being considered the better, though the slower, process.

We now come to the most important part of the whole operation—the tanning, properly so called. This used to occupy a very long time, in some instances as much as two years; but great attention has been paid to the shortening of its duration, and some plans have been devised by which it is possible to accomplish it in a fortnight or so. It is, however, found that a complete combination between the tannic acid and the gelatine is always a matter of time, an excess of the tannin being necessary in order to produce the required effect; and if the operation be performed too rapidly, an inferior leather is sure to be the result. The old plan was to put the hides in pits between layers of ground bark, and leave them there for months, until the bark was considered spent, when the process would be repeated with fresh material, and so on until the hides were sufficiently tanned. It was afterwards found to be more expeditious to introduce tepid water into the pits for the purpose of drawing out the tannin from the bark. Now, an extract of bark, technically called "ooze," is found to be still better. This may be made either with cold or warm water, and the strength of the solution can be regulated as may be desired.

In the tan-yard a series of pits are arranged, with feed-pipes for supplying the ooze, and in these the hides are laid, and then the liquor introduced. The hides must, however, be handled or turned over twice a day at first, being returned into the same or the adjoining pit, the pits being so arranged that the first contains the weakest ooze, and so on up to the strongest or concentrated solution. When they are passed into the stronger ooze, the hides are handled only once a day, and subsequently only once a week or more, up to a month. From this circumstance the pits containing the weakest solutions are called "handlers," and those containing the stronger are termed "layers" and "bloomers;" a concentrated solution being finally used in order to give a bloom to the leather. Heavy hides require usually a period of about eight months to tan them properly with oak bark, and about double their weight of bark; but if the other materials already named are used instead, a proportionately less quantity is required, and the time occupied is also somewhat shorter.

After being finally taken out of the tan-pits the hides have to be carefully dried in a moderately warm chamber, and are usually rolled under heavy brass rollers in order to give them more compactness and a better surface, upon which their marketable value considerably depends.

It has been already stated that the production of leather is due to the action of tannic acid upon the gelatine (of which skin is mainly composed), forming thereof an insoluble compound; but tannic acid has, unfortunately, a great tendency to become oxidised and pass into gallic acid, which will not precipitate gelatine, and cannot, therefore, convert a raw hide into leather. It is therefore necessary that such precautions should be taken as will prevent this chemical change, though in many tan-yards a good deal of gallic acid is produced without its being objected to, as it has the property of swelling the hides, and so rendering them more permeable to the tan liquor; however, the loss in the strength of the latter is not compensated by the action of the gallic acid. An exposure to the air at an elevated temperature is a common cause of the oxidation of the tannic acid; and this action is particularly liable to take place when the vegetable fibre of bark or sumach is left in the solution, the fibre apparently acting the part of a ferment in such cases. Should fermentation have set in, it may readily be stopped by the use of alcohol, carbolic acid, or other similar substances.

It will be seen from the foregoing that the tanning process is a singularly slow one, and though many plans have been suggested for shortening the time required, practical inconveniences have prevented their general application. The discovery of any simple means by which the operation could be materially expedited would confer a most signal benefit upon this large and increasing branch of trade.

PRINCIPLES OF DESIGN.—IX.

By Christopher Dresser, Ph.D., F.L.S., etc.

ART FURNITURE—CHAIRS.

Having considered those principles which are of primary importance to the ornamentist, we may commence our notice of the various manufactures, and consider the particular form of art that should be applied to each, and the special manner in which decorative principles should be considered as applicable to various materials, modes of working, and requirements of individual manufactures.

We shall commence by a consideration of furniture, or cabinet work—first, because articles of furniture occupy a place of greater importance in a room than carpets, wall-papers, or, perhaps, than any other decorative works; and, second, because we shall learn from a consideration of furniture those structural principles which will be of value to us in considering the manner in which all art objects should be formed if they have solid, and not simply superficial, dimensions.

In the present chapter I shall strive to impress the fact that design and ornamentation may be essentially different things, and that in considering the formation of works of furniture these should be regarded as separate and distinct. "Design," says Redgrave, "has reference to the construction of any work both for use and beauty, and therefore includes its ornamentation also. Ornament is merely the decoration of a thing constructed."

The construction of furniture will form the chief theme of this chapter, for unless such works are properly constructed they cannot possibly be useful, and if not useful they would fail to answer the end for which they were contrived.

But before commencing a consideration of the principles involved in the construction of works of furniture, let me summarise what is required in such works if they are to assume the character of art-works.

1. The general form, or mass form, of all constructed works must be carefully considered. The aspect of the "sky-blotch" of an architectural edifice is very important, for as the day wanes the detail fades and parts become blended, till the members compose but one whole, which, when seen from the east, appears as a solid mass drawn in blackness on the glowing sky; this is the sky-blotch. If the edifice *en masse* is pleasing, a great point is gained. Indeed, the general contour should have primary consideration. In like manner, the general form of all works of furniture should first be cared for, and every effort should be made at securing beauty of shape to the general mass.

2. After having cared for the general form, the manner in which the work shall be divided into primary and secondary parts must be considered with reference to the laws of proportion, as stated in my last article.

3. Detail and enrichment may now be considered; but while these cannot be too excellent, they must still be subordinate in obtrusiveness to the general mass, or to the aspect of the work as a whole.

4. The material of which the object is formed must always be worked in the most natural and appropriate manner.

5. The most convenient or appropriate form for an object should always be chosen, for unless this has been done no reasonable hope can be entertained that the work will be satisfactory; for the consideration of utility must in all cases precede the consideration of beauty, as we saw in my last chapter.

Having made these few general remarks, we must pass to consider the structure of works of furniture. The material of which we form our furniture is wood. Wood has a "grain," and the strength of any particular piece largely depends upon the direction of its grain. It may be strong if its grain runs parallel with its length, or weaker if the grain crosses diagonally, or very weak if the grain crosses transversely. However strong the wood, it becomes comparatively much weaker if the grain cross the piece; and however weak the wood, it becomes yet weaker if the grain is transverse. These considerations lead us to see that *the grain of the wood must always be parallel with its length whenever strength is required.*

For our guidance in the formation of works of furniture, I give the following short table of woods arranged as to their strength:—

Iron-wood, from Jamaica—very strong, bearing great lateral pressure.

Box of Illawarry, New South Wales—very strong, but not so strong as iron-wood.

Mountain ash, New South Wales—about two-thirds the strength of iron-wood.

Beech—nearly as strong as mountain ash.

Mahogany, from New South Wales—not quite so strong as last.

Black dog-wood of Jamaica—three-fourths as strong as the mahogany just named.

Box-wood, Jamaica—not half as strong as the box of New South Wales.

Cedar of Jamaica—half as strong as the mahogany of New South Wales.*

Wood can be got of sufficient length to meet all the requirements of furniture-making, yet we not unfrequently find the arch structurally introduced into such wooden objects while it is an absurdity so to do. The arch was a most ingenious invention, as it affords a means of spanning a large space with small portions of material, as with small stones, and at the same time gives great strength. It is, therefore, of the utmost utility in constructing stone buildings; but in works of furniture, where we have no large space to span, and where wood is of the utmost length required, and is stronger than our requirements demand, the use of the arch becomes structurally foolish and absurd. The folly of this mode of structure becomes more apparent when we notice that a wooden arch is always formed of one or two pieces, and not of very small portions, and when we further consider that, in order to the formation of an arch, the wood must be cut across its grain throughout the greater portion of its length, whereby its strength is materially decreased; while if the arch were formed of small pieces of stone great strength would be secured. Nothing can be more absurd than the practice of imitating in one material a mode of construction which is only legitimate in the case of another material, and of failing to avail ourselves of the particular mode of utilising a material which secures a maximum of desirable results.

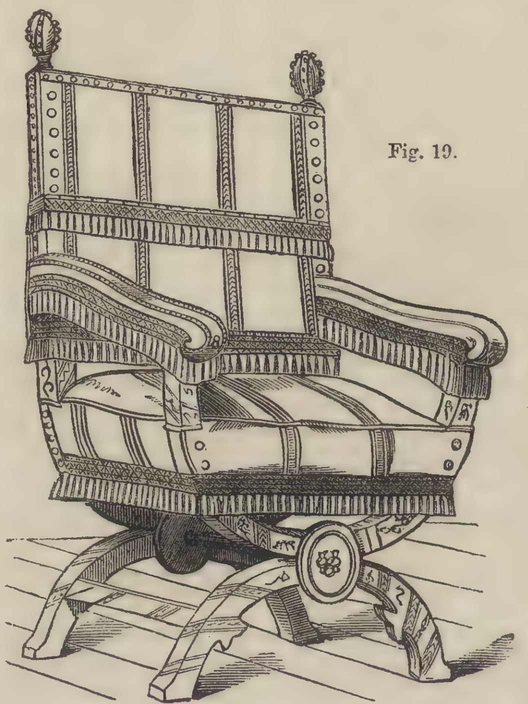


Fig. 19.

While I protest against the arch when structural in furniture, I see no objection to it if used only as a source of beauty, and when so situated as to be free from strain or pressure; but this matter I shall revert to when considering the formation of cabinets, when I shall illustrate my meaning more fully.

One of the objects which we are frequently called upon to construct is a chair. The chair is, throughout Europe and America, considered as a necessity of every house. So largely used are chairs, that one firm at High-Wycombe employs 5,000 hands in making common cane-bottomed chairs alone, and yet we see but few chairs in the market which are well constructed. All chairs having curved frames—whether the curve is in the wood of the back, in the sides of the seat, or in the legs—are constructed on false principles. They are of necessity weak, and being weak are not useful. As they are formed by using wood in a manner which fails to utilise its qualities of strength, these chairs are offensive and absurd. It is true that, through being surrounded by such ill-formed objects from our earliest infancy, the eye often fails to be offended with such works as it would be were they new to it; but this does not show that they are the less offensive and constructively wrong. Besides, whenever wood is cut across the grain, in order that we may get anything approaching the requisite strength, it has to be much thicker and more bulky than would be required were the wood cut with the grain; hence such furniture is unnecessarily heavy and clumsy.

Fig. 19 represents a chair which I have taken the liberty of borrowing from Mr. Eastlake's work on household art.* This chair Mr. Eastlake gives as an illustration of good taste in the construction of furniture; but I give it as an illustration of that which is essentially bad and wrong. The legs are weak, being cross-grained throughout, and the mode of uniting the upper and lower portions of the legs (the two semicircles) by a circular boss is defective in the highest degree. Were I sitting in such a chair, I should be afraid to lean to the right or the left, for fear of the chair giving way. Give me a Yorkshire rocking-chair, in preference to one of these, where I know of my insecurity, much as I hate them.

A chair is a stool with a back-rest, and a stool is a board or plane elevated from the ground or floor by supports, the degree of elevation being determined by the length of the legs of the person for whom the seat is made, or by the degree of obliquity which the body and legs are desired to take when using the seat. If the seat is to support the body when in an erect sitting posture, about seventeen to eighteen inches will be found a convenient height for the average of persons; but if the legs of the sitter are to take an oblique forward direction, then the seat may be lower.

A stool may consist of a thick piece of wood and of three legs inserted into holes bored in this thick top. If these legs pass through the upper surface of the seat, and are properly wedged in, a useful yet clumsy seat results. In order that the top of the stool be thin and light, it will be necessary that the legs be connected by frames, and it will be well that they be connected twice, once at the top of each leg, so that the seat will rest upon this frame, and once at least two-thirds of the distance from the top. The frame would now stand alone, and although the seat is formed of thin wood it would not crack, as it would be supported all round on the upper frame.

A chair, I have said, is a stool with a back. There is not one chair out of fifty that we find with the back so attached to the seat as to give a maximum of strength. It is usual to make a back-leg and one side of the back of the chair out of one piece of wood—that is, to continue the back-legs up above the seat, and cause them to become the sides of the chair-back. When this is done the wood is almost invariably curved so that the back-legs and the chair-back both incline outwards from the seat. There is no objection whatever to the sides of the back and the legs being formed of the one piece, but there is a great objection to either the supports of the back or the legs being formed of cross-grained wood, as much of their strength is thereby sacrificed. Our illustrations (Figs. 20—25) will give several modes of constructing chairs such as I think legitimate; but I will ask the reader to think for himself upon the construction of a chair, and especially upon the proper means of giving due support to the back, until such time as I converse with him again in my next article.

* For full particulars on this subject see "Catalogue of the Collection illustrating Construction and Building Material," in the South Kensington Museum.

* The title of the work is "Hints on Household Art." It is well worth reading, as much may be learned from it. I think Mr. Eastlake right in many views, yet wrong in others. I cannot help regarding him somewhat as an apostle of ugliness, as he appears to me to despise finish and refinement.

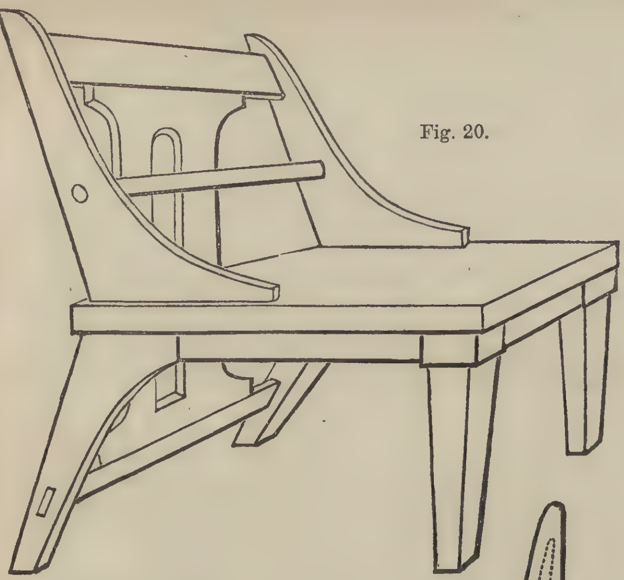


Fig. 20.

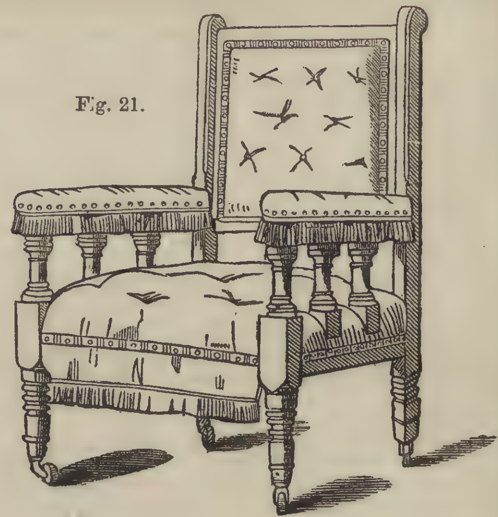


Fig. 21.

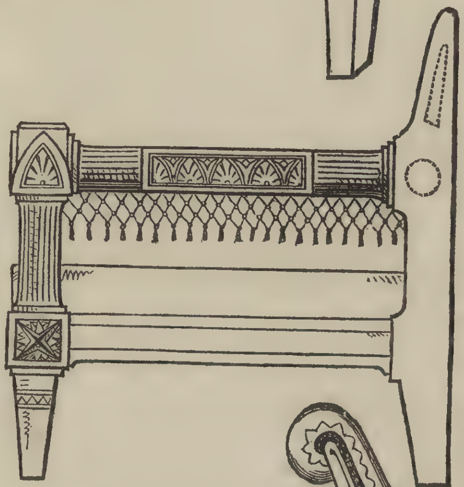


Fig. 22.

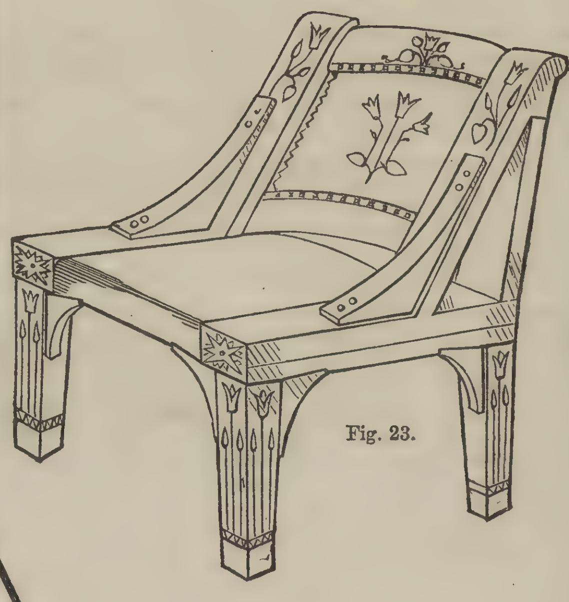


Fig. 23.

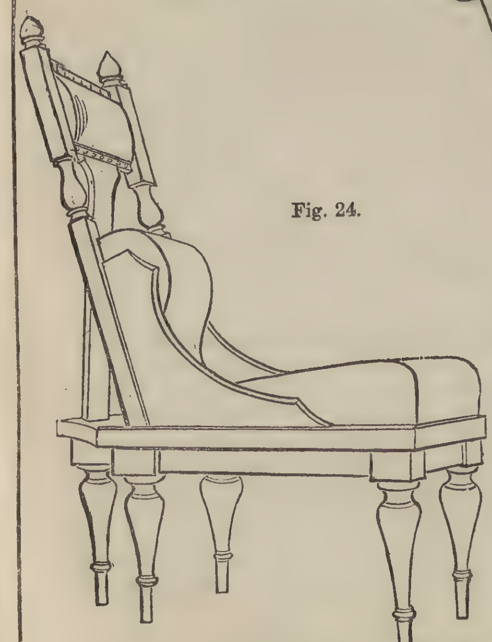


Fig. 24.

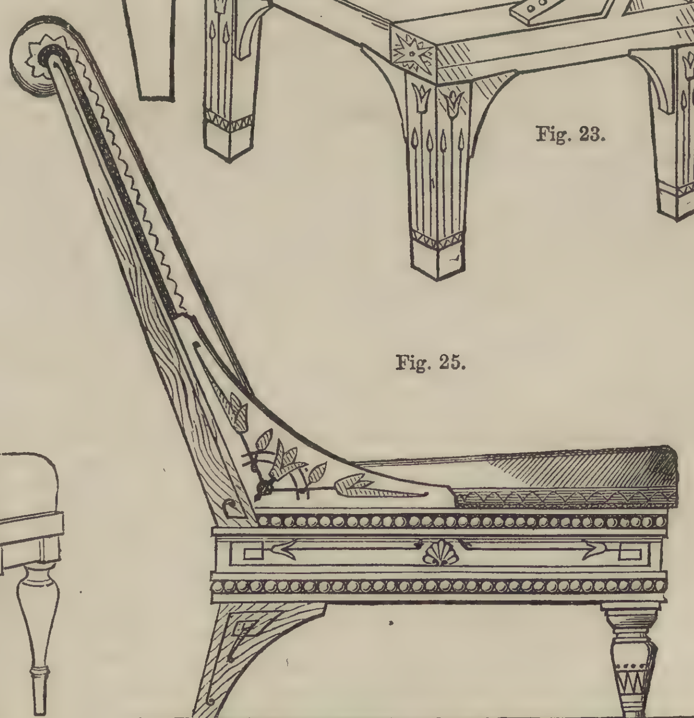


Fig. 25.

CIVIL ENGINEERING.—IV.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

ROADS—CANALS.

THE brief allusion we made in a former chapter to the excellent roads constructed by the Romans will indicate to the reader the fact that these, the most useful of all engineering works, are also amongst the earliest. No country can excel in commerce or arts which is destitute of good roads; and in colonising a new territory these are, or should be, the first points to which the engineer directs his attention; for without some mode of conveniently transporting the products of agriculture or of science from one locality to another, no country can flourish.

It is true that imperial Rome constructed her splendid highways rather with a view to the passage of her armies than to purposes of trade, but they were not the less available for more useful purposes either then or at the present time.

A good road is of use just in the proportion in which it permits of the heaviest loads traversing it in all weathers, with the least expenditure of power. Hence, the two main points to be aimed at in the construction of a road are (1) that it shall be *level*, and (2) that it shall have an *even surface*.

The first of these conditions can be attained only by a survey of the district through which the road is intended to pass. The desirability of a road being *horizontal* is too obvious a point to be enlarged upon; at the same time, unnecessary labour in excavating hills and in raising causeways or embankments over valleys must be avoided. A very slight alteration or temporary deviation from the direction of the proposed route will often be the means of saving an immense amount of labour and expense, without materially increasing the distance, the longest road being frequently the shortest in point of time. Where an extended chain of hills crosses the proposed route, it may become necessary to carry it over the ridge; but the gradient may be considerably diminished by cutting through the summit of the hill, and carrying the excavated soil into the adjoining valleys. Before deciding upon the exact point at which the ridge shall be cut, it will be desirable to examine the nature of the subsoil by frequent borings, as by this means rock may often be avoided.

The duties of the civil engineer may be said to have terminated after he has determined on the course to be taken by the road, and calculated the extent of the cuttings and embankments requisite; but it is absolutely necessary that he shall be practically acquainted with the nature of its construction, to enable him to check the operations of the contractor.

In order that a road shall possess an even surface, it must be composed of materials which will not readily yield to the traffic it will be subjected to. Durability, *in all weathers*, must be aimed at, and this is not always readily attainable. In a dry climate the difficulty is greatly diminished, but in so humid and changeable a climate as our own it is very much increased, whilst the passage of horses and vehicles aggravates the mischief. Hence the question how to construct durable roads in our large towns is one which can scarcely be said even now to be settled, seeing we are unable to pave the streets of even our most crowded cities with square blocks of stone, accurately fitted, as did the Romans.

First, as to *unpaved* roads:—

It must always be remembered that water, when not required, is the greatest enemy which the engineer has to contend with, and with roads it is no exception; hence, no matter of what material the road be constructed, it should be so formed as readily to throw off the rainfall. A moderately flat curve should be the figure given to the cross-section, the summit being in the centre of the road, and terminating at either side in a sunken channel to receive and carry off the water, which is far more injurious to the road when it is permitted to settle upon the surface. It then gradually soaks into the soil, rendering it soft and spongy, and the first vehicle which passes over it in this state produces an indent in which more water collects, and thus the mischief increases. On this account too much care cannot be bestowed upon the drainage.

The nature of the material employed in constructing a road is of the first importance, but a difficulty frequently arises in procuring the most suitable kind of soil in the district which the road is to traverse, and the haulage of which from a distance may involve an expenditure too great to be incurred.

Telford stands forward prominently as a road engineer. The great road constructed by him in 1816-17, from Carlisle to Glasgow, may be taken as an excellent example of a country road. Its length is 93 miles; it is 34 feet wide between the fences; but the central portion only, for a width of 18 feet, is *metalled*—that is, laid with broken stones; the remaining portion on either side is gravelled. Its cost was £1,000 per mile. The advantage of *metalling* a road lies in this, that the traffic itself assists to consolidate and harden the bottom. The metalling should consist of granite, broken with the hammer, by which the least quantity of the block is pulverised, and the stones retain the sharpness of their edges and angles, thus facilitating their entrance into the soil. The broken stone is spread in a layer over a subsoil, prepared to receive it either by a rake or a pickaxe—the thickness of the layer being regulated according to the nature of the bottom—the furrowing by the pickaxe being requisite to give a hold to the metalling. A light sprinkling of gravel is occasionally thrown over the metalling, which affords an easier footing for quadrupeds, and is in no way detrimental to the formation of the road. The process of metalling by spreading broken stones over the surface is called "macadamising," after the name of the inventor, Macadam, and in this manner may be constructed excellent country roads, suitable, with proper attention, for all ordinary traffic. The *bottom* usually consists of broken stone or brick, rubble, burnt earth, bushes—anything, in fact, which by the action of moisture will not form mud.

The character of the subsoil has much to do with the durability of a road. If it be soft, broken granite, even thickly strewn, will prove a useless because an unendurable surface. This was found to be the case on the road under the Highgate Archway, where, owing to the soft and yielding nature of the subsoil, the only artificial surface which stood the wear and tear of the ordinary through traffic was a composition of gravel and Roman cement, in the proportion of 1 bushel of cement to 8 bushels of washed gravel and sand—the cost being about 2s. per square yard for a thickness of six inches.

Many instances will occur in which the ordinary macadamised road will prove of no value—for example, in building a road across a bog or morass. In this case the plan adopted originally by Metcalf, in the last century, and subsequently by Stephenson, at Chat Moss, has been proved the most efficient. The yielding character of the bog would entirely absorb any soil thrown directly upon it; but by employing a *floating* medium, such as fagots, brushwood, or furze, and extending the width of the base considerably beyond what is required for the purposes of traffic, the soil may be made to rest upon the floating platform, and the road thus formed will efficiently bear up the weight of passing traffic.

A macadamised road is of comparatively little use in a busy town. A *through* traffic is not nearly so injurious to a road as a traffic in which vehicles are often turning—the pivot-wheel acting as a scoop, and producing an abrasion of the surface.

The character of the surface of a road has, as may be supposed, much to do with the amount of friction existing in wheeled traffic. On a gravelled road the friction is 4·5; on an old flint road it is 2·0; a well-made pavement being reckoned as 1·0—facts which at once settle the question of the desirability of maintaining a good surface on a road.

It is an interesting fact, in connection with our subject, that the injury done to an ordinary macadamised road by four horses is three times as great as that done by four *coach*-wheels, but this proportion is considerably increased when the wheels are broad as in wagons. The fact that horses are so injurious to the surface of roads led to the effort, made many years since by Mr. Gurney, to introduce steam-power upon common roads in lieu of horses.

No ordinary macadamised road will withstand the traffic of the streets of large towns without the most continuous attention, and a consequently large outlay. The more usual mode of meeting the difficulty is by a regular paving of stone, of which there are two kinds—the *rubble* and the *ashler*. A rubble is in reality an imperfectly constructed ashler pavement. The ashler causeway consists of hammer-dressed granite stones, from five to seven inches thick, eight to twelve inches long, and twelve inches deep. These stones are laid in regular order upon a foundation consisting of cement, sand, and gravel, which is allowed to set firm, the surface of this bottom being

adjusted by suitable tools to the curve which the cross-section of the finished road is intended to assume. After the surface-stones are arranged upon this bed, they are "set" by a copious discharge of thinly-mixed mortar being thrown over them, which settles down into the interstices between the stones and fixes them. The cost of a well-constructed ashler road varies from 7s. to 10s. per superficial yard. As compared with a macadamised road this is, of course, a high figure; but the difference is only in the first cost, and disappears when the item of maintenance is considered.

In some instances a still more expensive kind of road is constructed to meet special cases, as, for instance, the exceptionally heavy traffic between the Docks and the City of London, or over London Bridge, in which continuous lines of large granite blocks are laid end to end, with flush joints, thus forming a level stone tramway in the wheel-tracks. The blocks vary from 2½ feet to 10 feet long, are 18 inches wide, and 12 inches deep. Such a tramway so far reduces friction as to enable a single horse to draw a load exceeding ten tons at a rate of nearly four miles an hour, an advantage so obvious that, after the success of the experiment had been proved, it was proposed to lay a roadway of the same description between London, Liverpool, and Holyhead, upon which steam carriages might run. The idea was, however, rejected, as it was proved that, with all the care which could be bestowed upon such a road, the friction was still vastly in excess of that upon a smooth iron rail.

A rubble pavement is one in which less care is bestowed upon the shaping and dressing of the stones; hence there is less uniformity in their arrangement, and consequently wider interstices between them.

The maintenance of a roadway is an important item of expense. We have stated that a good ashler road costs much less to keep it in repair than a macadamised road, the maintenance of the latter costing about 2s. 11d. per superficial yard per annum; but as macadamised roads cannot be entirely dispensed with, it is important to ascertain the best and the most economical method of keeping them in repair. The tendency of traffic is to wear down the surface from an erect curve to a level, or even to an inverted arch—the principal traffic being naturally confined to the centre of the road. This change of figure must be prevented, in order to keep up the lateral drainage; the application of broken stone to all low parts must, therefore, never be neglected. The accumulation of mud must also be carefully avoided. A scraper is usually employed for the latter object, but this implement is, without a doubt, the greatest enemy an ordinary road possesses. Even with the use of Bourne's Multi-dental Scraper it is impossible to prevent the teeth from catching the projecting points of stone, the result of which is that the stone is dragged out of its bed, and a hole is formed. Nor does the mischief end there, for the surrounding stones, which were previously firmly wedged, become loose, and the solidity of the surface is impaired. The broom is the only thing that should be employed to remove loose mud from the surface, and this, if frequently applied before any large accumulation of soil has arisen, will always prove sufficient for the purpose; for, besides doing its work with less injury to the road, it does it better than the scraper, entering more searchingly into the inequalities of the surface.

It must be admitted that an ashler road, however excellent, is productive of great noise, and an uneasy vibration to the occupants of vehicles passing over it. For this reason, *wooden* blocks have, in several instances, been employed instead of stone; and if this description of pavement could be made as durable, it has manifest advantages over the granite-paved surface. It is almost noiseless—too much so, indeed, for the safety of pedestrians—and the absence of jolting from stone to stone, combined with the yielding character of the surface, is productive of much less injury to the hoofs of the animals and to the springs of the carriages. An attempt has been made to render the surface of the wood more durable by studding it thickly with large-headed nails, but this course has not been successful. Knapp's pavement consists of hollow iron blocks, divided into small compartments, filled with concrete to a level with the surface. Four of these blocks make one square yard. Asphalte has been recently employed in some of the busiest of the London thoroughfares. It forms an excellent surface, and an agreeable road, but its durability remains to be proved.

Canals.—The advantages arising from a system of communication which, whilst extending over the interior of a country, is at the same time connected more or less directly with the great highway of nations, the sea, are obvious. But there are other and equally apparent advantages in connection with water transit, advantages which are, however, particularly applicable to *heavy* goods. For instance, the tractive power of a wagon-horse upon a good road may be reckoned at 140 kilogrammes, whilst a *single man* is capable of drawing a load 350 times as great when floating upon water. Friction, in fact, is reduced almost to *nil* when the load is floating, providing the speed is inconsiderable; indeed, the limit of weight to which a man is thus capable of imparting motion is not easily ascertained, but it appears to be bounded only by the *vis inertia* of the mass. The advantages, therefore, of canals as means of transport are evident, and vast sums of money have been expended upon their construction in this and other countries. There are, however, serious difficulties in the formation of a canal, requiring considerable talent and forethought on the part of the engineer to overcome.

The first point for consideration is whence to obtain the necessary water-supply. If the course of the canal were one continuous level throughout, communicating at either extremity with some large reservoir retaining a uniform level, there would be no further supply required than what was demanded by evaporation, or absorption by the soil; but if the surface to be traversed is irregular, the introduction of *locks* becomes necessary, and every barge which passes through a lock creates a demand upon the water supplied from the higher ground. The expense of employing pumps to return the water back to the higher level could not for a moment be entertained, except as an expedient during a limited period in dry weather; it is imperative, therefore, that an adequate supply of water should exist to provide for the loss arising from the emptying of the locks; and the highest level of the canal should be so arranged as that it should receive at all times an equable and adequate supply of water from that source.

Next in importance to the water-supply is the consideration of the course to be traversed by the canal. The commercial advantages arising from the contiguity of the canal to large towns must enter largely into the calculations of the engineer in his determination of this point; but above all he must be guided by a consideration of the nature of the surface and subsoil. If the subsoil be porous, consisting of sand or gravel, an undue loss of water will arise from absorption, to prevent which a large outlay must be incurred in puddling the channel with clay; for this reason an absorbent soil should be avoided if possible. A matter of equal importance is the character of the surface; every effort must be made by the engineer to prevent unnecessary excavation, and at the same time to limit as far as possible the number of *locks*, those expensive and inconvenient but indispensable adjuncts to a canal, a further consideration of which we shall reserve for our next chapter.

The engineer is much more restricted in his actions in preparing the plans for a canal than he is in laying out a road, or even a railway, because any deviation from an absolute level is inadmissible without the introduction of a lock. It is usual to lay out a canal in sections, the space intervening between lock and lock—and which therefore occupies the same level—being regarded as a *section*. The object of the engineer is, therefore, to make each section as long as possible, and as direct as the nature of the ground will admit. It is, of course, impossible to maintain one uniform level throughout; but by judiciously availing himself of the side of a hill, winding round its side, and selecting a short valley intervening between one hill and another, and spanning it by an aqueduct, and again skirting the side of another hill, and so on, the number of locks may be greatly reduced. An apt illustration of the skill displayed by the engineer in the selection of the ground may be quoted in the case of the Monmouthshire Canal, which traverses very difficult ground, but which, winding round the side of the Blorenge at the height of several hundred feet above the valley of Crickhowell, enters the upper end of the valley in its course towards Brecon upon one continuous level throughout.

In other instances—for example, the Rochdale Canal between Rochdale and Todmorden—the character of the ground necessitates the use of locks at very short intervals, involving a vast outlay in the first instance, and a great impediment to navigation in the second.

TECHNICAL DRAWING.—XX.

DRAWING FOR MACHINISTS AND ENGINEERS.

FREE-HAND DRAWING (*continued*).

FIG. 209 is a sketch of a common padlock, which affords a good subject for the practice of balancing curves.

Having drawn a central perpendicular, and a horizontal line crossing it, set off the widths A B and A C; then, having determined on the distance A D, draw the curve on the left side—viz., B D—and balance it by the curve C D.

Observe that these curves must not form a point at D, but must merge smoothly into each other.

Fig. 210 shows the key of this padlock.

Having drawn a central line, and another at right angles to it, draw the rectangle A B C D. Set off E, F, G, H, and thus eight points will be obtained, through which the elliptical head of the key is to be drawn.

It must, however, be understood, that this squaring out of curved forms is merely intended to assist the student in the most elementary stage, and must be discontinued as soon as possible.

The barrel and remaining portions of the key are now to be drawn, and will easily be understood from the copy.

Fig. 211 represents a small iron cramp.

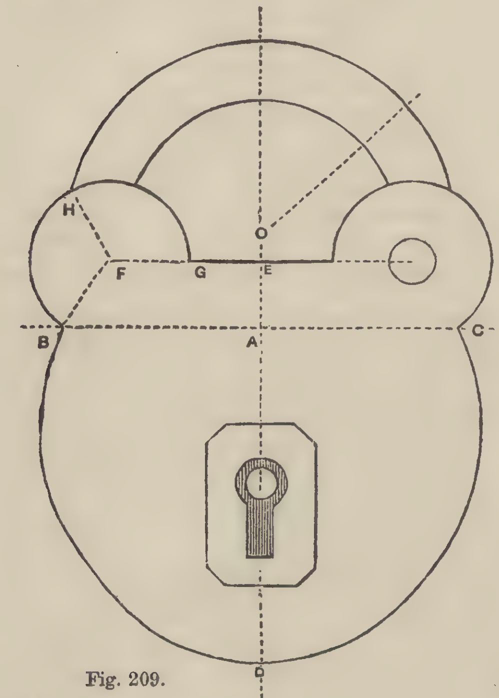


Fig. 209.

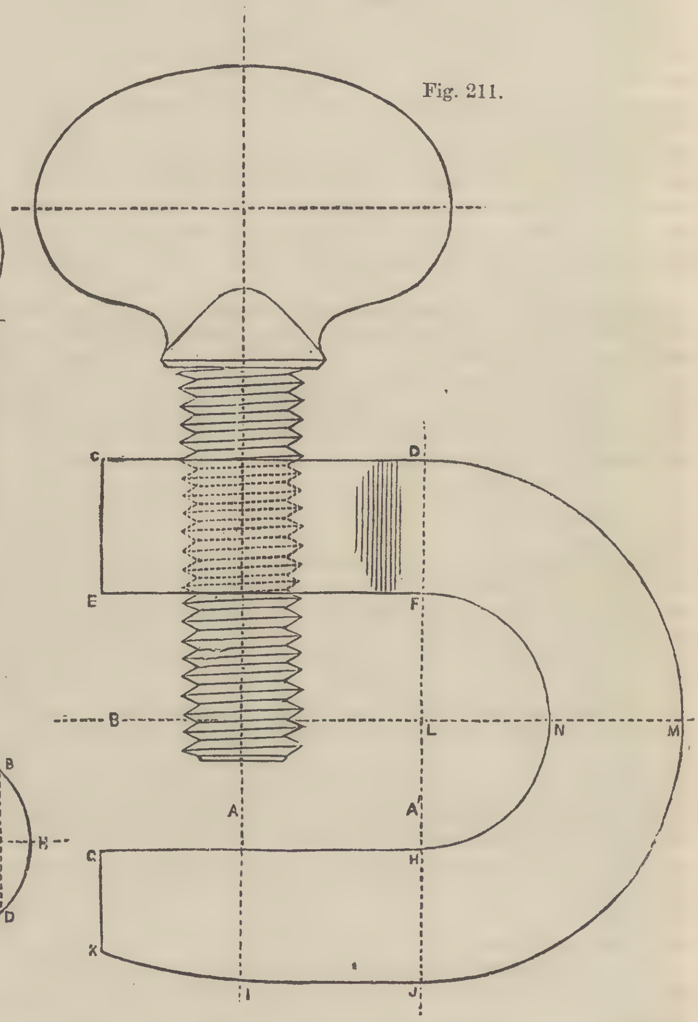


Fig. 211.

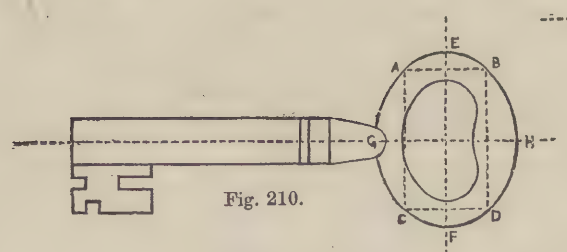


Fig. 210.

Now draw a horizontal line at E, and mark on it, on each side of the central line, a distance corresponding with E G.

Produce this line, and continue the curve beyond B until it meets the straight line in F. The length from G to F and from B to F will then be equal, and thus a circle drawn from F, with the radius F G, would also include B.

Now to draw circles by hand is, to almost all persons, a rather difficult task, but it may be rendered less so by drawing lines from the centre, and marking off on them the radius required, as shown at F H. The curve may then be traced through the points thus obtained. The segments of circles on each side, then, having been drawn, and also the smaller circle representing the rivet, draw the upper portion of the padlock, the centre being at O; and in this, too, the method shown above may be adopted. The keyhole, and plate surrounding it, can, it is hoped, be drawn without further instructions.

Draw the perpendicular A, the horizontal B, and the perpendicular A', at the required distance from A.

Now draw the horizontals C D, E F, G H, and I J, the extremity of I J being carried upward in a curve to K. Join C E and G K. From L set off L M, equal to L D, and also from L set off L N, equal to L F, and draw the semicircles D M J and F N H, which will complete this portion of the object.

Having drawn the handle of the thumbscrew in the manner shown in the callipers and padlock, draw the perpendiculars for the inner and outer angles of the thread of the screw. The method of drawing a screw in the simplest manner has been shown in Fig. 205. In the present study, however, the lines are to be drawn by *hand* instead of by the aid of the rule.

No further separate studies of free-hand drawing will be given, as it is intended that the student should copy the rough sketches and as many of the mechanical studies by *hand* as he can.

MECHANICAL DRAWING (*continued*).

Fig. 212.—The subject of this lesson is a *rachet-wheel.* This is a contrivance consisting of a wheel, with pins or teeth of a suitable form, which receives an intermittent circular motion from some vibrating piece. In this drawing, E is the rachet-wheel, furnished with saw-like teeth. The driver is a *click* or *paul,* A, jointed at one end to a movable arm, B, which has a vibrating motion on the shaft C as a centre. As B moves towards the left hand it pushes the wheel before it through a certain space, and on its return the click, A, slides over the points of the teeth, and is ready again to push the wheel through the same space as before, being pressed against the teeth either by a spring or its own weight. A *detent,* D, prevents the wheel from receding, whilst the click is moving over the teeth.

The first step in drawing this figure is to trace the two circles between which the teeth are to be contained.

These should be very lightly drawn, as no portion of either circle is to be used in the drawing; but they are required to ensure uniformity in the teeth.

Now, divide the outer circle into the number of parts required for the teeth. There is no special reason why the outer circle should be divided rather than the inner; it is merely that errors in division are more readily seen in large than in small circles. Where numerous divisions are required, some draughtsmen draw a circle outside the one to be divided, and of a much

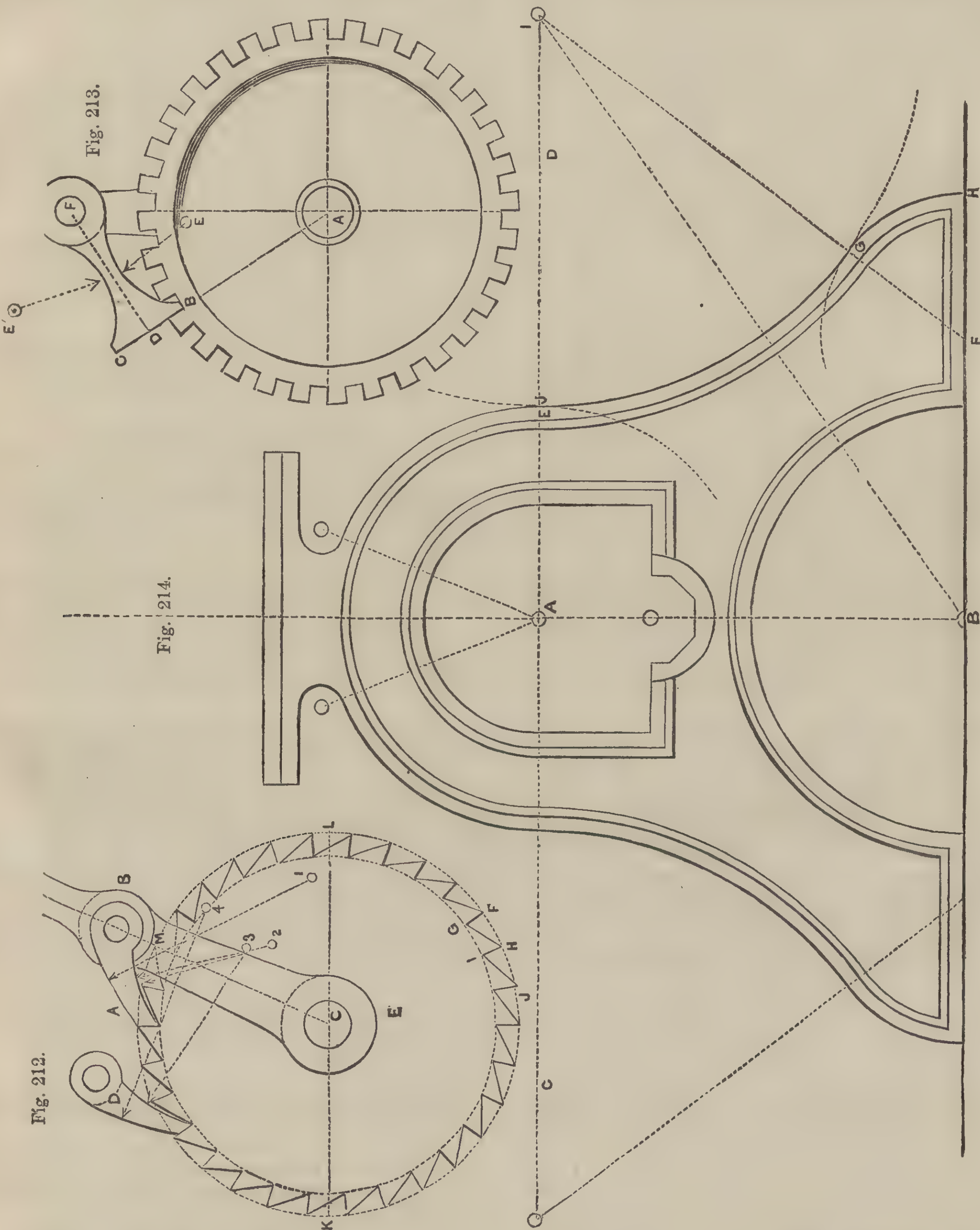


Fig. 213.

Fig. 214.

Fig. 212.

larger radius; on this they set off the required divisions, and from them draw lines to the centre; these lines passing through the original circle, divide it without fraying the paper or otherwise injuring the clearness of the work.

The outer circle then being divided, draw lines to the centre; it will not be necessary to draw these radii the whole of the distance, but only between the two circles, to form the faces of the teeth, as shown at F G, H I, etc.

Join the outer end of each line to the inner end of the next, as H G, J I, etc. These lines will form the backs of the teeth.

We now proceed to the arm, and for this the centre line must be drawn. Now it is necessary that, in copying a drawing, the exact inclination of such an arm or other part should be accurately given. To accomplish this, draw the diameter K L, measure from L on the circumference of the circle the length of the arc L M, and draw a line from the centre C through M.

Then construct on your drawing an angle similar to L C M, and the line C M will give the inclination required. This method can be applied without reference to size, for it will be remembered that the number of degrees an angle contains is not altered by the length of the lines of which it is formed.

Having then drawn the line C M, set off on it the centre of the click, and complete the arm, setting off the widths on the circles at top and bottom. The straight sides are to be joined to the circles by small arcs, or by curves drawn by hand.

The centres for the click and detent, and those from which their inner and outer curves are struck, are to be found in the same way.

It will be seen that, owing to the form of teeth shown in this figure, the wheel can only be driven in one direction; but in machines for cutting metal it is frequently necessary that it should work either one way or the other. Sir Joseph Whitworth adopts in such cases the construction shown in Fig. 213, called Clement's catch.

Here the rachet-wheel has teeth, the ends of which are bounded by the circle, and the flanks of which are portions of the radii, whilst the click is so formed that it will either work as shown in the example, or may be turned over to act in the opposite direction.

In drawing this figure, describe the circles for the inner and outer ends of the teeth; divide the outer circle into the required number of equal parts, the teeth and spaces being equal; draw the sides of the teeth by lines from the points of division to the centre, and join those lines which are to form teeth on the outer circle, and such as are to form spaces on the inner circle.

The click is now to be drawn. Having fixed the centre, F, draw the line B C, which is radial to the circle.

Bisect B C in D, and the bisecting line D F will be the central line for the click; the centres for the arcs forming the sides are shown at E and E′.

Fig. 214 is a portion of the *frame of a pump*, and is here introduced as a study in joining circles, the whole of the external form being described by portions of three circles touching each other.

Having drawn the base-line and perpendicular, B, mark on it the point A, and through it draw the horizontal C D.

With radius A E, describe a semicircle.

From B set off B F.

From F, with radius F G, describe the arc G H.

From F draw a line through G, cutting the line C D in I.

From I, with radius I J, describe an arc, joining the semicircle to the arc last drawn. The rest of the drawing being obvious, it is hoped that, after this fundamental construction has been correctly done, the remaining portion will be accomplished without further instructions.

COLOUR.—VI.

By Professor CHURCH, Royal Agricultural College, Cirencester.

COLOURS WITH WHITE, GREY, AND BLACK—OCULAR MODIFICATIONS OF COLOUR—PERSISTENCE OF COLOUR-IMPRESSIONS—IRRADIATION—SUBJECTIVE COLOURS—CONTACT AND SEPARATION OF COLOURS.

WE have seen, in the last lesson, that there are two kinds of contrast—the contrast produced by difference of tone and the contrast produced by difference of colour. We have also seen that these contrasts are produced under several conditions, and that they are modified through the mode in which they are perceived by the eye and impressed upon the mind. No sooner, in fact, are two colours so placed as to be seen at the same time or in quick succession, than they are apparently changed. The change may be one of tone only, of colour only, or of both tone and colour. Nor is it necessary, in such experiments, that two colours should be used: we may employ two tones of the same colour or a single tone of colour with white, grey, or black. We have already studied the apparent changes which the primary and secondary colours mutually cause when placed in contiguity, and so may now proceed to state what modifying influences white, grey, and black respectively produce upon the most important colours (see Figs. IX., X., and XI. in coloured plate).

1. YELLOW.—*Yellow* with *white* is rendered darker, less luminous, and less prominent, and acquires a faint greenish hue. The lighter the tone of the yellow, the less pleasing is the combination.

Yellow with *grey* is rendered darker, less luminous, and perhaps a trifle more orange. When the grey is of about the same intensity or tone as the yellow, the combination is not satisfactory; but it becomes so when the grey is rather deep, the yellow then recovering brightness.

Yellow with *black* is rendered lighter or paler, more luminous, and more prominent. The combination affords the most intense contrast next to that of white with black. The blackness of the black acquires a somewhat bluish-violet hue, which has a tendency to enrich it.

2. ORANGE.—*Orange* with *white* is rendered darker, and perhaps a trifle more reddish. The contrast between orange and white is much greater than that between yellow and white, and the combination is consequently more effective.

Orange with *grey*, when the latter is pale, is darkened and reddened. With deep tones of grey, orange becomes more luminous.

Orange with *black* becomes more luminous and yellower; the contrast is next in intensity to that afforded by yellow with black.

3. RED.—*Red* with *white* becomes more intense and of a deeper tone. The combination, as to intensity of contrast, is similar to that of green with white; being less decided than that of blue and violet with white, but more so than that of yellow and orange with white.

Red with *grey*, where the latter is pale, becomes more intense, deeper, and occasionally acquires a slight bluish hue.

Red with *black* becomes more luminous and slightly yellower.

4. VIOLET.—*Violet* with *white* affords a contrast of very decided character, owing to the great difference of tone between a full violet and white. The violet is rendered deeper in tone in this combination.

Violet with *grey*.—The distinctive colour of the violet makes itself felt in this combination, which is a quiet and agreeable one.

Violet with *black* affords an instance of the harmony of analogy rather than of contrast. The violet is enriched by its proximity with black; but the latter thereby acquires a rusty hue, which takes away from its richness.

5. BLUE.—*Blue* with *white* constitutes a pleasing combination. The contrast is very decided where the tone of blue is deep. The effect of white clouds in deepening the tone of the sky is a good example of one of the chief characteristics of this combination.

Blue with *grey*.—Grey enhances the tone and quality of blue, deepening it to a remarkable extent under certain circumstances.

Blue with *black*.—This combination resembles that of violet and black, but is less agreeable, especially where the blue is of a deep tone. Light shades of blue are rendered paler and more luminous by contiguity with black.

6. GREEN.—*Green* with *white* becomes more intense and of a deeper tone; green is distinctly improved by the presence of white.

Green with *grey* becomes deeper in tone.

Green with *black* is rendered rather lighter in tone, and more brilliant; but the black suffers in purity, and becomes slightly tinged with a ruddy hue—the result of adding to the black, red, the complementary colour of the neighbouring green.

From what has been said in the preceding paragraphs, it will

have been seen that the effect of white upon a colour is to enhance its quality and deepen its tone; for white, presenting the maximum of luminosity itself, naturally lowers the apparent luminosity of coloured surface in contact with it. (We employ the term *luminosity* here in its common acceptation, not in its scientific sense as previously explained in Lesson I.) But the white is capable of enhancing the quality of a colour for a different reason (explained already when speaking of "Simultaneous Contrasts"). In virtue of this principle, the white, in contiguity with a colour, has a tendency to become tinctured with the complementary of that colour; the presence of this trace of the complementary colour enhances the quality of the original colour itself, in obedience to the law of contrast: the same effect is observed, also, with grey and black when placed in contiguity with colours.

This remarkable law of contrast, of which we are now speaking, may, indeed, in its widest terms and most general application, be summed up in the statement that two differing colours or differing tones tend, when placed together, to differ still more. Light tones and colours become lighter, dark tones darker, complementary colours are mutually enhanced in distinctness; and where a colour is present without its complementary, that complementary is, as it were, evolved, owing to extra sensibility of the eye for those colours which are not presented to it when it has been excited and fatigued by those at which it has been gazing. Before studying the more complex combinations of colours and their applications in the arts, it will be expedient to develop a little more fully some of those principles on which the "subjective" or "ocular" modifications of colours depend. To such phenomena we have just now, as well as on former occasions, briefly alluded; but we are now in a position to extend and amplify our previous observations.

The subjective modifications which colours suffer arise from at least three causes.

First of all, we have the persistence of the impression on the retina of the eye.* The discharge of a Leyden jar gives a spark which is sensibly instantaneous, and yet the impression which it makes upon the eye endures a distinct fraction of a second. The spokes of a rapidly-revolving wheel are seen with perfect distinctness and perfectly separate if it be illuminated by an electric spark, although in an ordinary light they may present a shadowy surface, where all the elements of the wheel are blended together. Yet the apparent solidity of this surface may be proved to be unreal by its approximative transparency to objects placed on the further side of it. These objects, if properly lighted, can be readily perceived through the shadowy surface previously described. Similarly with a series of flashes of electric sparks; if these follow one another at intervals less than the period during which the impression of each spark remains upon the retina, the resultant effect will be that of a continuous light. A familiar example of this persistence of impressions upon the retina is to be found in the experiment of rapidly whirling a glowing stick or piece of red-hot charcoal; a continuous circle of light being produced under these circumstances, if the rotation be sufficiently rapid. Now the effect of this peculiarity of the optical arrangements of the human eye is very marked in the case of colours; but it does not take place exactly in the direction in which we might expect it. It would be imagined that if one of the eyes has been looking at a yellow disc or other yellow object it would perceive, when directed upon a blue object, a mixture of yellow and blue, or a colour lying between them. However, under such circumstances the blue object, so far from acquiring a greenish tinge, becomes rather tinctured with a violet hue. This effect is really one of subjective colour, as well as of persistent vision; for the eye having seen a yellow object is partially blinded or paralysed, so far as that component of white is concerned; acquiring, on the other hand, greater sensitiveness to the perception of the complementary of yellow—that is, violet. White surfaces, or even coloured surfaces, which, of course, reflect much white light, will then have their violet or red and blue constituents brought into unusual prominence by the previous perception of yellow, and will be consequently tinctured with violet. As it is difficult to carry out mentally, from this principle, the whole scheme of alterations of colour effected by the peculiar kind of contrast just described, we shall here give a list of the principal colours as modified by the previous perception of others. Before doing so, it may be advisable to give our readers a method of proving for themselves that such modifications really occur.

Close the right eye, and then look steadily with the left at a sheet of *red* paper. When the red paper appears dull, owing to the special sort of fatigue it induces in the eye, look immediately, still with the left eye, upon a sheet of *violet* paper. The violet paper receiving the complementary of red—namely, green—becomes much bluer. To verify this observation it is only necessary, after having closed the left eye, to open the right, and to look with it upon the sheet of violet paper. The violet will be perceived very differently now, and so far from being bluer than in reality, may actually appear modified in the contrary direction—becoming more red, instead of more blue. To be performed with successful and distinct results, such experiments as these require great care and frequent repetition. Moreover, different individuals have very different powers of appreciating colours and of recording their impressions. One eye, also, will often be found to differ from its fellow in many important particulars. Notwithstanding the delicacy and difficulty which may be experienced in determining the special relations of contrast (often called "mixed contrast") now under consideration, they are of considerable importance in the practice of some kinds of decorative art.

We now give our list of the modifications induced by mixed contrasts of colour.

If the eye has first seen	*and then looks at*	*the latter colour will appear*
Yellow,	orange,	reddish-orange.
Yellow,	red,	reddish-violet.
Yellow,	violet,	bluish-violet.
Yellow,	blue,	violet-blue.
Yellow,	green,	bluish-green.
Orange,	yellow,	greenish-yellow.
Orange,	red,	reddish-violet.
Orange,	violet,	bluish-violet.
Orange,	blue,	tinged with violet.
Orange,	green,	bluish-green.
Red,	yellow,	greenish-yellow.
Red,	orange,	yellow.
Red,	violet,	indigo-blue.
Red,	blue,	greenish-blue.
Red,	green,	bluish-green.
Violet,	yellow,	slightly greenish.
Violet,	orange,	yellowish-orange.
Violet,	red,	orange-red.
Violet,	blue,	greenish-blue.
Violet,	green,	yellowish-green.
Blue,	yellow,	orange-yellow.
Blue,	orange,	yellower.
Blue,	red,	orange-red.
Blue,	violet,	reddish-violet.
Blue,	green,	yellowish-green.
Green,	yellow,	orange-yellow.
Green,	orange,	reddish-orange.
Green,	red,	tinged with violet.
Green,	violet,	reddish-violet.
Green,	blue,	violet-blue.

It must not be forgotten that the above modifications of colour, arising from mixed contrast, differ not only in intensity, but in persistence. The modification produced by the successive view of violet and yellow is stronger and more persistent than that produced by the successive view of blue and orange; green is but slightly modified, and for a brief space of time only, by the previous view of red, and so on. And the above-described effects of contrast are influenced, to a great degree, by the difference of tone between the colours successively observed. A dark blue viewed after orange may actually appear somewhat greenish, when the normal modification would be precisely in the opposite direction—that is, towards violet; yet this change occurs most conspicuously when the blue is of not too full a tone. Among the most important cases, constantly occurring in common life or artistic practice, of modifications of colours arising from persistence of the impressions made on the retina, we may cite the difficulty experienced by painters, from gazing too long at any bright coloured object, natural or artificial, of reproducing or

* Illustrations of the remarkable effects produced by persistence of vision, and the imitation of this natural effect by various scientific toys, will be found in that portion of "Recreative Science" which appears in Vol. VI. of THE POPULAR EDUCATOR.

matching its tone and hue. Again, we may allude to the well-known instance of the purchaser of coloured fabrics. If a series of bright yellow fabrics be displayed, and then some pieces of orange or red stuff, this latter is regarded as dull, and to have a crimson or even a violet tinge. Under such circumstances, the retina, fatigued by the sight of yellow, has a tendency to appreciate and perceive violet, its complementary, more distinctly. Thus much of the yellow in the orange stuff is suppressed, and it appears redder than it really is; red similarly acquires a violet tinge. Doubtless much of the weariness experienced by a long examination of the pictures in an exhibition of modern works of art is due to eye-fatigue, and the consequent ocular modifications of colour.

The second subjective or ocular cause of apparent changes in the colours of objects is due to a defect of the organ of vision. The eye suffers from what in optical language is termed "spherical aberration"—a scattered light, of varying degrees of intensity, always surrounding the defined images of luminous and strongly illuminated objects upon the retina. The result of this nebulous border about such images is to increase their apparent size; but it is nearly always imperceptible under the ordinary conditions of moderate illumination. When, however, we look at incandescent or glowing and luminous bodies, the effect is very striking. A piece of charcoal no thicker than one's finger, if lighted at one end and plunged in oxygen, appears actually to swell as the combustion becomes more intense and the light brighter. A spiral of platinum wire heated to whiteness by a galvanic current not only has its diameter, so far as the wire itself is concerned, enormously increased, but the separate turns of the spiral seem to approach and even to coalesce, if not originally too distant. The crescent of the moon appears, for the same reason, to belong to a much larger sphere than the dimmer mass of the satellite which it clasps. Much of the peculiar indefiniteness and mystery which impart considerable beauty to flames of different kinds, to strongly illuminated clouds and surfaces of water, and to the intense reflected lights of metallic ornaments, is due, in part at least, to irradiation, which, moreover, is one of the chief causes by which coloured margins are so frequently observed to surround coloured objects. A rim of greenish light may be observed round a red wafer placed on white paper, owing to the extension of the image of the red wafer beyond its geometrical image on the retina of the eye. Of course the rim is green, owing to the effect of simultaneous contrast. With a pure yellow, such as that of the spectrum, or that made by mixing green and red *lights* together, the rim of irradiate colour would be blue. This effect is roughly shown in Fig. III. of our coloured plate.

The third ocular cause of the modification of colour has been already dwelt upon at some length, and in different places, in the present series of lessons: it is the production of subjective complementary colours. We may just allude to the phenomenon here, in order that this most important and fundamental fact may be thoroughly impressed upon the minds of our readers. Simply stated, the cause of the phenomenon may be traced to the impaired sensibility to light temporarily caused by the action of light upon the optic nerve. Not only is this true of white light, but of light of every colour. Not only does a moderately lighted room appear dark when we first enter it from broad sunshine, but, as we have before stated, the last piece of yellow or red cloth we look at will seem duller than the first, though they have all been cut from the same roll. When light of any particular colour falls upon the eye, it becomes less sensitive to, and less appreciative of, that colour; it is partially blinded to its perception. So, not only will a red wafer placed upon a sheet of white paper be surrounded by a rim of colour through irradiation, but that rim will be green; and if the wafer be moved away, a green spot will occupy its former position. For the eye, by gazing at the red wafer, has had its sensibility to red light temporarily impaired, and so the white light received on that particular spot of the retina previously occupied by the red tinge of the wafer will have its red constituent virtually removed, and will produce the effect of the residual rays—namely, a green image, the complementary of the previous red one. Several other contrivances for producing subjective complementary colours have been devised. One of the most satisfactory of these is to view a surface of white, grey, or coloured paper, moderately illuminated, through an aperture in another sheet of paper of a different colour, and placed at a little distance above or before it. The lower surface, as seen through the aperture, will be tinged with the complementary of the coloured surface above. So, also, the shadow of an object interposed in a beam of coloured light will, if received on a screen slightly illuminated with white light, appear to have assumed the colour complementary to that of the beam; and, for the same reason, a beam of daylight finding its way into a room illuminated with yellowish light from candle-flames, will appear violet. The importance of this fact, as regards the proper treatment of shadows in painting, will have to be insisted on and illustrated farther on in the present course.

We have now studied the mutual effects of many pairs of colours, the effects of white, grey, and black upon single colours, and the effect on a second colour of the previous perception of another. We have then passed to the causes, dependent upon the structure of the human eye, which modify the natural appearance of coloured objects. We may fitly close this lesson with a few remarks on the uses which may be made of some of the facts and laws which have just been stated, confining our attention at present, however, to those effects of the apposition and separation of coloured spaces which are illustrated in our coloured plate.

We have before stated that the yellow is the most forcible, luminous, and prominent of the primary colours. It will appear nearer to the eye than either red or blue. In Fig. IV. (coloured plate) a yellow leaf pattern is represented upon a ground partially red and partially blue. While there is no doubt of the prominence of the yellow, it will probably be allowed that the red ground appears nearer than the blue; and if the blue had been of a purer and fuller tone still, the retiring effect which it possesses would have been still more perceptible. How far the retiring effect of blue is due to association or fancy, to our constant view of the sky and the hazy distance of a landscape, it is difficult to determine. But there can be no doubt that we are obliged, in decorative and pictorial art, to recognise the idea of distance conveyed by blue and bluish hues, and that such colours afford means of attaining effects of mystery, obscurity, hollowness, etc., which other hues do not furnish. Another association with the colour blue is that of coolness, just as red recalls the glowing warmth of a fire, and yellow the bright shining of the sun. Another feature of our diagram (Fig. IV.) is the distinctness of the sensation imparted by the three colours, yellow, red, and blue. If the red approaches the yellow rather more closely than the latter does the blue, it arises from the impossibility of representing by actual pigments these three colours.

Figs. V. and VI. teach another fact relating to coloured spaces in contact. Often when we attempt to mix colours, our mixture is anything but successful. The difficulty of getting a good violet by adding blue and red together is well known. The result may be achieved in a different way. If lines or dots of red and blue be distributed suitably over a surface, the effect of violet will be produced—at all events, when the figure is held at some distance. One mode of accomplishing this result is seen in Fig. VI., where the distinction of the two colours is lost, and a mixed colour effect produced, in obedience to the laws of subjective colours already announced. In Fig. V. the two colours retain their distinctness at ordinary small distances.

When two colours of about the same intensity and tone, as the blue and yellowish or leaf-green in the central stripes of Figs. VII., and VIII., are in contact, there is a want of distinctness and purity about the margins of the contiguous colours, which renders the combination by no means a pleasing or favourite one. Yet a bright leaf-green is often seen in Nature against the deep blue of a summer sky, and no one dreams of quarrelling with this arrangement of colour. There are, however, delicate differences between the natural and artificial appositions of green and blue. The green leaves of trees are full of minute variations of tone, structure, and form, and they are further helped to contrast with the more uniform blue beyond them by the reflected illumination of some of the edges and the shading or darkening of others. The latter modification may be represented to us roughly in Fig. VIII. Here we see the enormous importance of white and of black, even in the narrowest lines and smallest quantities, in separating related colours. Such colours, difficult as they are to harmonise successfully under many ordinary conditions, afford by the aid of black or white combinations of great delicacy and beauty.

ANIMAL COMMERCIAL PRODUCTS.—XIII.

I.—DYES.

Some of the Mollusca furnish dyes and pigments. The *Murex* yields various shades of purple and crimson. The celebrated Tyrian purple was formerly obtained from *Murex trunculus.* The cuttle-fish (*Sepia officinalis*), which clouds the water by ejecting from its ink-bag a deep black fluid, thus effectually concealing itself, supplies the well-known pigment, *sepia*, of a deep brown-black colour; and a calcareous spongy plate, found in the same fish, is used as a substitute for emery or sand-paper, and as a dentifrice.

II.—SHELLS.

The beautiful variety of form and colour in shells has in all ages attracted notice. Among savages shells are used for personal adornment, and made into domestic utensils, such as knives, spoons, drinking-cups, fish-hooks, and even razors. The wampum belts of some of the North American tribes are made of shells. A small species of white glossy shell, called cowry (*Cyprœa moneta*, Figs. 1, 2), abundant in the Asiatic and African shores, is used as money in small payments in India and throughout extensive districts in Africa, 100 being equivalent to one penny. The same cowries are converted into a glaze for earthenware and an enamel for clock faces. *Cyprœa coccinella* (Fig. 3) is found in the English Channel. The thin inner layers of a large flat bivalve (*Placuna placenta*) found in the Chinese sea, remarkable for their transparency and the absence of the nacreous or pearly layer within, are used by the Chinese for windows instead of glass. In Roman Catholic countries clam shells form receptacles for holy water; while some, perfectly white, are cut up for arm-rings and other ornaments. The *Voluta gravis*, or chank shell of India, fished up by divers in the Gulf of Manaar on the north-west coast of Ceylon, is exported to India, where it is sawn into rings of various sizes, and worn on the arms, legs, fingers, and toes, by the Hindoos. The demand for these shells is caused by the religious rites of the Hindoos, and some choice specimens of them are valued at their weight in gold. The helmet shell (*Cassis*, Fig. 4) supplies pieces large enough for umbrella handles, and the nacreous or inner layers of this shell, and other species, are exquisitely sculptured by Italian artists in imitation of antique cameos, and employed for rings, brooches, pins, bracelets, and other ornaments.


Fig. 1.

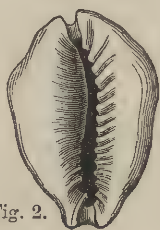


Fig. 2.


Fig. 3.

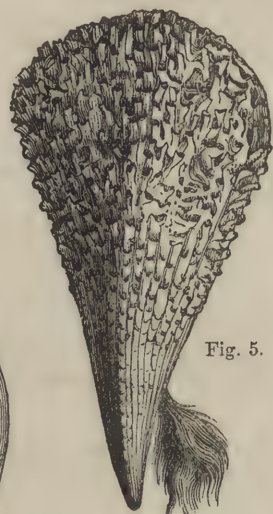


Fig. 5.


Fig. 6.

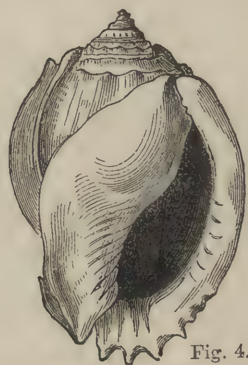


Fig. 4.

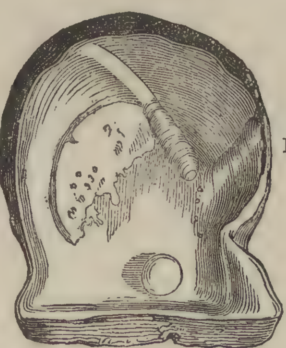


Fig. 8.

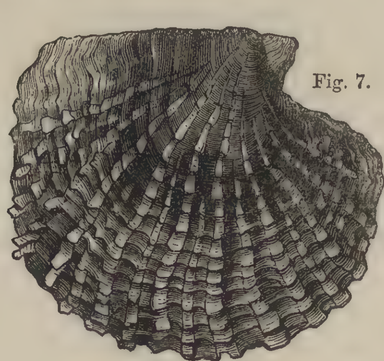


Fig. 7.

The *byssus*, or fasciculus of shining semi-transparent horny or silky filaments, by which many kinds of bivalves attach themselves to rocks, is in the large *Pinna* or wing-shell (Fig. 5) so much developed, that by the natives of Sicily it is manufactured into gloves, socks, caps, etc., of a beautiful brownish colour. These are valuable as objects of curiosity, but too expensive for general use, the price of a pair of gloves being six shillings, and that of a pair of stockings eleven shillings.

The large proportion of lime in shells renders them useful in making cement, and valuable as a fertiliser of the soil; and for this reason shell-sand, the product of their natural crumbling on sea-shores, is employed with advantage in improving heavy loams and clayey or peaty soils. Mixed with any soil deficient in lime, shell-sand exercises a beneficial influence.

If we look at a shell we shall find it to consist of three layers, viz., one external and rough, a medium layer consisting of delicate super-imposed laminæ of polygonal prisms, and an internal and shining one called the nacre, which is composed of a series of extremely delicate deposits, unequal in size and extent, and therefore imbricated in their position on each other, their margins presenting a series of lines with waved edges. These wrinkles, or furrows, which are of microscopic proximity and minuteness, decompose the rays of light, and produce that beautiful iridescent play of colours visible on the surface of the shell. It is this nacreous lustre which renders shells so capable of being applied to ornamental purposes, and gives to them their principal commercial importance.

The brilliancy of the colours reflected depends on the thinness of the laminæ of the nacre. Where the laminæ are thick, a dull white appearance only is visible, as in the oyster. Sometimes the external layers covering the nacre are rubbed off by natural causes, as in the case of shells which have been subjected to the roll of the waves on the sea-shore, where quantities may be found having the bright and iridescent nacreous surface exposed, but more or less injured; generally, however, these outer layers are removed artificially with a knife, and the shell is polished. This nacreous layer is the well-known mother-of-pearl, and shells having it in the greatest abundance are called pearl shells, such as the sea-ears (*Haliotis*) and a large species of top-shell (*Turbo marmoratus*, L., Fig. 6). Mother-of-pearl, in consequence of its lamellar structure, admits of being split into laminæ; or it is cut, without being split, into square, angular,

or circular pieces, which are employed extensively in the arts, particularly in inlaid work and in the manufacture of knife and razor-handles, buttons, snuff-boxes, and toys. Cut into the form of leaves, flowers, and other devices, it forms a favourite material for ornamenting *papier-maché*—a name given to articles manufactured from paper pulp, which is moulded into varied forms, and rendered as hard as wood by being dried in an oven.

The most valuable shells in commerce are, however, those which form the nacre into the fine, compact, concentric layers called pearls. These pearls are sometimes found free within the lobes of the mantle, but most frequently adhere to the nacreous coat of the shell. The species which produces the largest and most valuable pearls is the

Pearl Oyster (*Meleagrina margaritifera*, L., Figs. 7, 8).—The most valuable pearl fisheries are those on the western coast of Ceylon; at the Bahrein Islands in the Gulf of Persia; at Tuticoreen, on the coast of Coromandel; off St. Margarita, or Pearl Islands, in the West Indies; in some places on the coast of Columbia; and in the Bay of Panama in the Pacific. Very large and beautiful pearls, too, are said to have been found recently on the peninsula of California. The fisheries in the Persian Gulf are the most valuable, giving employment to 4,000 boats and about 30,000 people, and yielding a revenue of more than 2,500,000 thalers (£375,000) a-year.

The value of pearls depends upon their size, purity, and lustre. The best are spherical, free from spot or stain, and have a clear, bright, white or yellowish-white, or bluish colour, with a peculiar lustre or iridescence. They vary in size—some not bigger than small shot, and others as large as a pea or bean. When pearls dwindle to the size of small shot, they are called seed-pearls, and are then of little value. "A handsome necklace of Ceylon pearls, as large as peas, is worth from £170 to £300; and one of pearls the size of peppercorns may be had for £15."* The largest and most valuable pearl of which we have any authentic account was purchased by Tavernier, at Catifa, in Arabia—a fishery famous in the days of Pliny—for the enormous sum of £10,000. It was pear-shaped, two inches in length, and half an inch in diameter, and is now the property of the Shah of Persia. The finest pearls generally pass under the name of "Oriental pearls;" and those with less lustre and beauty, even if they do come from the East Indies, are called "Occidental pearls."

Pearls are most abundant in the pearl oyster, which appears to be subject to a disease, caused by the introduction of foreign bodies within the shell. A pearl, if cut through, will generally show a nucleus, formed by a grain of sand or some other foreign body, around which the nacreous matter has accumulated in concentric deposits, instead of being spread in the usually horizontal laminæ on the inside of the shell.

The value of pearls has been greatly depreciated in modern times through the successful imitation of them. The spurious glass and wax pearls now made in Paris, Venice, Nuremburg, and Bohemia have much diminished the trade in real pearls. The best imitations were first made by a French bead-maker named Jacquin. The water in which the fish called the bleak (*Cyprinus alburnus*) is washed, is filled with powdery particles, which shine with a pearly lustre. Jacquin noticed this; he called this powder "essence of pearl," or "*essence d'Orient*," and succeeded in covering the inside of glass beads with it, thus producing a most admirable spurious glass pearl. A considerable trade is done with spurious pearls on the coasts of Senegambia, Guinea, and Congo, and the adjacent islands, where they are indispensable goods for the transaction of business with the natives.

NOTABLE INVENTIONS AND INVENTORS.

VI.—THE MARINER'S COMPASS.

BY JOHN TIMBS.

THE contrivance by which the magnet, in the very middle of a strip of iron, is still true to the distant pole, and remains a faithful guide to mariners, is the compass, before the invention of which—

"Rude as their ships was navigation then,
No useful compass or meridian known;
Coasting, they kept the land within their ken,
And knew no north but when the Pole-star shone."

If we hang up a magnet by a thread, or allow it to swim in quicksilver, or place it in a small bit of wood floating in water, it never comes to a state of rest until one end points to the north and the other to the south. The needle or index of a compass is a prismatic piece of tempered steel, which, by having been rubbed on a magnet, has acquired a magnetic power, and which, being placed on a pivot, is at liberty to turn in all directions.

This accidental discovery of the property of a natural substance rapidly influenced the fortunes of mankind. "In the development of the commercial spirit of the Crusades, Providence is seen in its most manifest footsteps. Sitting upon the floods, it opens to new enterprises. The compass, twinkling on its card, was a beam from heaven; that tiny magnet was given as a seigniory of earth and sky. Like a new revelation, the mysteries of an unknown world were unveiled; like a new illapse, the bold and noble were inspired to lead the way. Dias doubles the Cape of Storms; De Gama finds his course to the East Indies; Columbus treads the Bahamas; and twelve years do not separate these discoveries."

The compass was the invention; the discovery which preceded it—for there must be a discovery preceding every invention—was the finding of the natural magnet or loadstone; and "this did more for the supplying and increase of social commodities than those who built workhouses," as said the grave philosopher, John Locke. The power of the loadstone to attract iron was known to the ancient Egyptians, who, however, did not apply it to any practical purpose. It is referred to by Aristotle and by Pliny, who tell us that ignorant persons called it quick-iron; and in the Middle Ages it was believed to possess medicinal properties, as an alterative and cure for sore eyes. Tiger Island, at the mouth of the Canton river, in China, consists chiefly of magnetic ore, and mariners say that the needles of their compasses are much affected by their proximity to the island. Tradition extends the story to drawing the nails and iron bands from the planks of ships, and thus causing them to fall to pieces; and it is remarkable that Chinese writers place the above magnetic island precisely in the region of the story of the voyages of Sindbad the sailor.

At what period the *polarity* of the magnet, or its disposition to turn to the north and south poles of the earth, was first discovered is not known. The Chinese appear to have known it from a very remote date, and to have extended it through most of the leading countries of Asia; the magnetic compass being used on land service prior to service at sea. Extracted from the Szuki of Szumathsian, a Chinese historian contemporary with the destruction of the Bactrian empire by Mithridates I., we find the following extraordinary relation: "The Emperor Tchwingwang, 1,110 years before our own, presented to the ambassadors of Tong-king and Cochin-China, who dreaded the loss of their way back to their own country, five magnetic cars, which pointed out the south by means of the moving arm of a little figure covered with a vest of feathers." "To each of these cars, too, a hodometer, marking the distance traversed by strokes of a bell, was attached, so as to establish a complete dead reckoning." (Humboldt's "Cosmos.") "A thousand years before our era, in the obscure age of Codrus, the Chinese had already magnetic carriages, on which the movable arm of the figure of a man continually pointed to the south, as a guide to find the way across the boundless grass-plains of Tartary; nay, even in the third century of our era—therefore at least 700 years before the use of the mariner's compass in the European seas—Chinese vessels navigated the Indian Ocean under the direction of magnetic needles pointing to the south." Klaproth has collected from Chinese authorities many curious anecdotes of the use of those chariots. Under the Tsin dynasty they formed a part of every royal procession. Whatever was the position of the car, the hand of the prism always pointed to the south. When the emperor went in state, one of these cars headed the procession, and served to indicate the cardinal points. The magnetic wagons or cars were made as late as the fifteenth century; several of them were carefully preserved in building the Buddhist monasteries, in fixing the points towards which the main sides of the edifice should be placed. Humboldt mentions the circumstance, that the magnetic land car used in China had attached to it a way measure. Over the trackless land, they were more certain of their course than the seaman of this age, who imperfectly ascertains the speed of his vessel by the log-

* See *Pearls*, "Dictionary of Commerce," by J. R. McCulloch. Also "Journal of the Society of Arts," No. 896, Vol. XVIII.

line, is uncertain of his leeway, and has to correct all by the observation of the heavenly bodies for his latitude and for his longitude, the time by a watch showing the difference of noon at his place of observation and the part from which he started." Thus writes Mr. Buckton to "Notes and Queries," 3rd Series, No. 257, adding: "Mr. Scoresby (afterwards a clergyman) was the owner and master of a ship in the North whale-fishery from Liverpool. In a lecture delivered by him thirty-four years ago, he exhibited an important experiment, which does not appear to be generally known. He took a bar of iron two or three feet long, about one inch in diameter, and placing it in the direction of the magnetic meridian—that is, pointing to the north, at an angle of 40° or 50° with the horizon—he struck it a smart blow with a heavy hammer, by which from a simple bar of iron it became a magnet. Afterwards he placed the same iron bar in a direction at right angles to its former position, and striking it as before, its magnetism was thereby discharged, and it was proved to have none of the properties of a magnet. At the time I considered this a favourable illustration, although not so designed by Scoresby, of the magnetic theory of Euler, disclosed in his 'Letters to a German Princess.'"

The history of the compass in Europe has been much controverted. The twelfth century is assigned as the period of its introduction into Europe; but it does not appear to have been then brought into common use for nautical purposes. Though passages of various dates speak explicitly of the use of the compass for land purposes, yet no mention of the magnet for *navigation* occurs, in any Chinese books that have come to the knowledge of Europeans, till the dynasty of Tsin, which lasted from the year 265 to 419 A.D. It is in the great dictionary, Roi-wen-you-fou; and it is there stated that "there were then iron ships directed to the south by the needle." Sir John Davis contends that this passage rather refers to the magnitude of their ships, and the extent of the voyages which they performed, than to the introduction of the needle into marine affairs. In the ninth century two Mahometan travellers are stated to have traded in ships to the Persian Gulf and the Red Sea, and though the *compass* is not mentioned, it is utterly improbable that the Chinese should have known the directive property of the magnet, and have used it on land in thirty centuries, and yet not have employed it at sea.

It was known on the Syrian coast before it had come into general use in Europe, as is obvious from a passage in a manuscript written in 1242, which thus describes the natural compass: "We have to notice, among the other properties of the magnet, that the captains who navigate the Syrian sea, when the night is so dark as to conceal from view the stars which might direct their course according to the position of the four cardinal points, take a basin full of water prepared for the purpose by placing it in the interior of the vessel; they then drive a needle into a wooden peg or acorn-stalk, so as to form the shape of a cross, and throw it into the basin of water prepared for the purpose, on the surface of which it floats. They afterwards take a loadstone of a sufficient size to fill the palm of the hand, or even smaller, bring it to the surface of the water, give to the hands a rotatory motion towards the right, so that the needle turns to the water's surface; they then suddenly and quickly withdraw their hands, when the two points of the needle face north and south. They have given me ocular demonstration of this process during our sea-voyage from Syria to Alexandria in the year 650 of the Hegira." When we consider the jealousy with which all knowledge was guarded by its possessors, especially that of *commercial* value, we cannot but admit that the use of the compass must have been very common at a period when a passenger was initiated into the complete knowledge of the mode of magnetising the steel needle, as well as the mode of using it.

About 1260, according to Dante's teacher, the needle was highly useful at sea, but the navigators were prejudiced against its adoption; for, says he, "no master-mariner dares to use it, lest he should fall under the suspicion of being a magician; nor would even the sailors venture themselves out to sea under his command, if he took with him an instrument which carries so great an appearance of being constructed under the influence of some infernal spirit." Dante refers, in a simile, to "the needle which points to the star;" and Raymond Lully, in 1286, remarked that the seamen of his time employed "instruments of measurement, sea-charts, and the magnetic needle."

The earliest mention of the primitive mariner's compass in English records is that in a work by Alexander Neckam (born about 1150), entitled "Treatise on Things pertaining to Ships." In the reign of Edward III. the magnet was known as the Sail-stone, or Adamant, and the compass was called the Sailing-needle, or Dial; though it is long after this period that we first find the word *compass*. Chaucer, who died in 1400, mentions the compass, and the sailors reckoning thirty-two points of the horizon, which is the present division of the card. Dr. Gilbert, physician to Queen Elizabeth, and who bestowed much attention upon magnetism, compared the earth to *a great magnet;* and in our time Faraday said, "The earth is a great magnet; its power, according to Gauss, being equal to that which would be conferred if every cubic yard of it contained six one-pound magnets; the sum of the force is, therefore, equal to 8,464,000,000,000,000,000,000 such magnets." The use of the word *compass* had become familiar in the reign of Charles I., and Rowe, in his Play of "Jane Shore," speaks of "the seaman's compass."

Sir John Ross, during his last voyage in the *Felix*, when frozen in about 100 miles north of the magnetic pole, concentrated the rays of the full moon on the magnetic needle, when he found it was five degrees attracted by it. A curious notion has been current, more especially on the shores of the Mediterranean, that if a magnetic rod be rubbed with an onion, or brought into contact with the emanations from that plant, the directive force will be diminished, while a compass thus treated will mislead the steersman. "It is difficult," says Humboldt, "to conceive what could have given rise to so singular a popular error." ("Wonderful Inventions," 1868.)

TECHNICAL DRAWING.—XXI.

DRAWING FOR MACHINISTS AND ENGINEERS.

FIG. 215.—The subject of this lesson, based on a study in Professor Bradley's excellent large work, is a *dead-beat anchor escapement.* The escapement wheel would carry the seconds hand of an astronomical clock.

The pallets are shown in two positions, when the pendulum has vibrated through one arc.

Draw the circles A and B, and divide A into the number of equal parts corresponding with the number of teeth required.

From each of these points draw lines touching the circumference of the circle B, as shown by the lines C D and E F.

Draw the circle G, and with the radius divide it into six equal parts: the radii drawn from these will be the centre lines for the arms.

Now from the points of the teeth draw tangents to the circle G, as shown in the lines H J and I K.

The lines H J and I K will cut the lines C D, and the other faces of the teeth, in points L, M, etc., all of which will be situated on the circle, and thus C L will be the depth of the face of the teeth.

The line H J, etc., will also give the upper part of the backs of the teeth, as H O, the length of which is fixed by the circle O.

The remaining portion of the backs of the teeth are drawn as shown in another tooth.

From P and Q, with any convenient radius, describe arcs cutting each other in R; then from R describe the arc P Q.

The student is again reminded, that to find the centre from which any arc of a circle is struck, three points are to be marked on the arc, and the lines uniting them are to be bisected; the intersection of the bisectors will then be the centre of the arc.

On each side of S set off S T and S U, for the width of the arms at their upper end.

Draw the circle V, and from W set off W X and W Y, for the width of the arms at their lower end.

Draw T Y and U X for the edges of the arms; but as these arms do not run as straight lines into the rim, but are connected by curves, the lines must only be fully drawn from *t* to Y and from *u* to X.

The distance *t* T may be carried round to each of the arms by a circle. On this circle set off *t* T′ equal to *t* T, and from T′, with radius *t* T′, draw the arcs connecting the edges of the arms with the inside of the rim.

The arms are connected at the bottom by circles of any convenient radius, as shown in the drawing at Z and Z′.

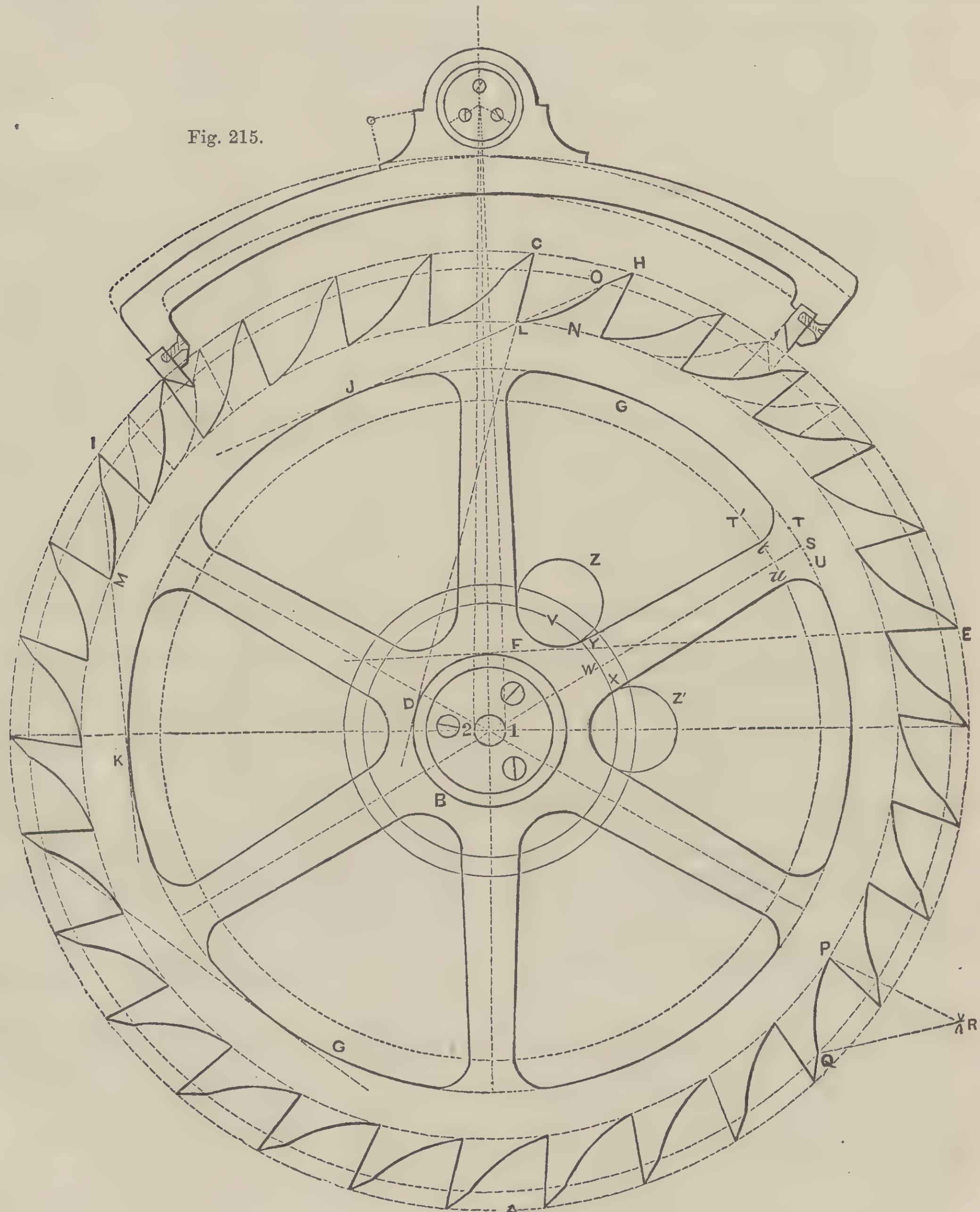
The anchor in its first position is an arc drawn from 1, whilst in its second position the arc is struck from 2.

The remaining portion of the drawing is left to the student's knowledge; and this plan will be constantly adopted, in order to release him as soon as possible from leading-strings, and by throwing him more and more on his own resources, give him

It is unwise to set off points from each other, for if either one be at all inaccurate, the error is carried on throughout the work, whereas if all the distances are set off from a centre line, any error will be confined to any one point which may have been inaccurately measured.

For the same reason the horizontal line G H is to be drawn,

Fig. 215.



the opportunity for exercise of thought and ingenuity, with the conviction that each success will give confidence, and inspire him with the desire for further exertion.

Fig. 216 is the front, and Fig. 217 is the side elevation of a *crank*, to draw which the student will require but few instructions. The centre line, A B (Fig. 216), is to be drawn first, and a horizontal line having been drawn at A, the distances A C, A D, A E, A F are to be set off, and perpendiculars drawn from them. The distances of the other perpendiculars are to be set off from the centre line. This plan is to be universally adopted.

and on each side of this half the widths of the end of the crank, the crank-pin, etc., are to be set off.

In Fig. 217 the distance from centre to centre, A B, is to be first marked, and from these the different concentric circles are to be described.

The lines C D and E F are next to be drawn near the circles at right angles to A B. On these the widths of the crank are to be marked, and the lines C E and D F are to be drawn. The subject will now be easily completed.

Unless formed in one complete forging, the crank, however

important in machinery, labours under the disadvantage of requiring the shaft to be divided, as shown at I and J in Fig. 216, unless when placed at the end; and therefore, when a crank of a small throw is wanted, as in the mechanism for moving the slide-valves of a steam-engine, the eccentric may be substituted brass or gun-metal for the purpose of diminishing friction, is accurately fitted within projecting ledges, D, on the outer circumference of the eccentric, so that the latter may revolve freely within it. This ring is connected by a rod, E, with a system of levers by which the valve is moved.

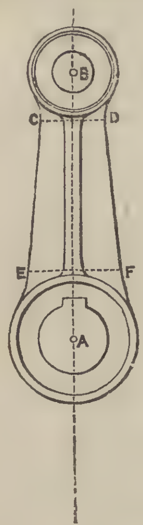


Fig. 217

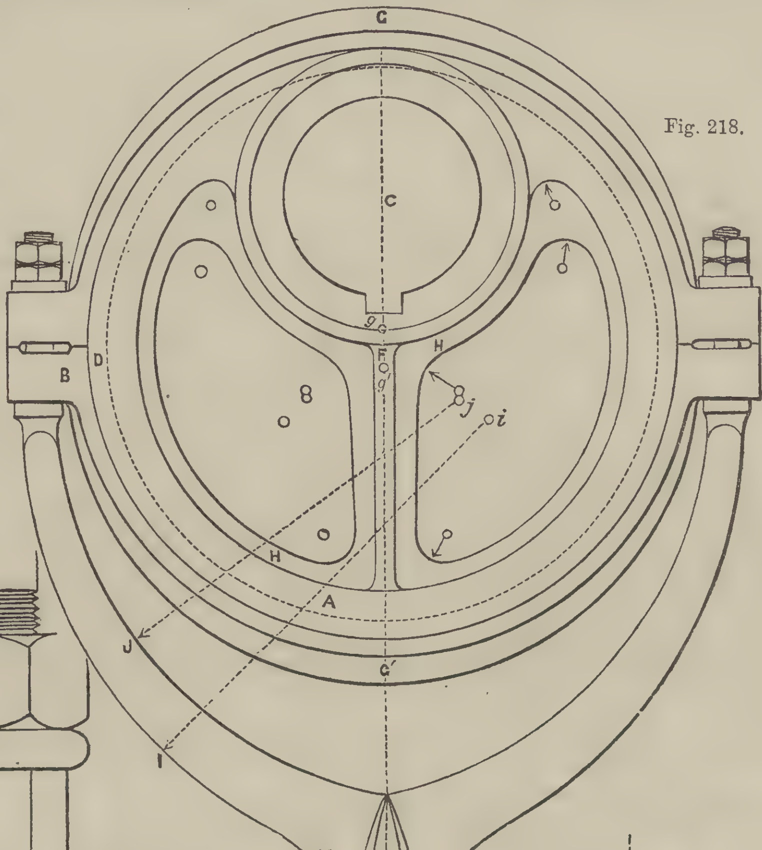


Fig. 218.

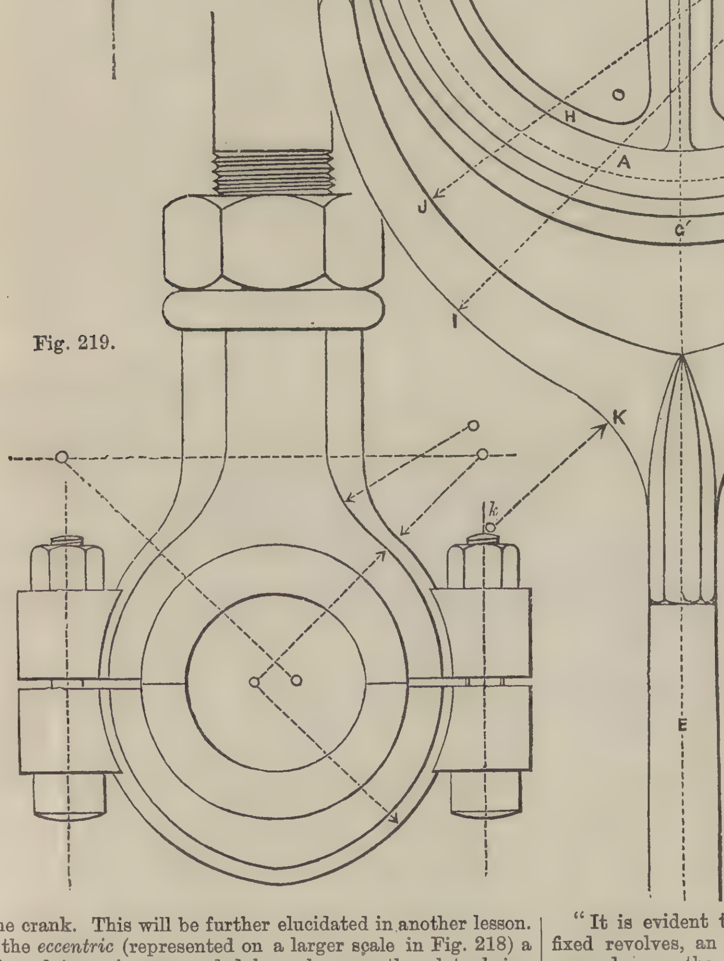


Fig. 219.

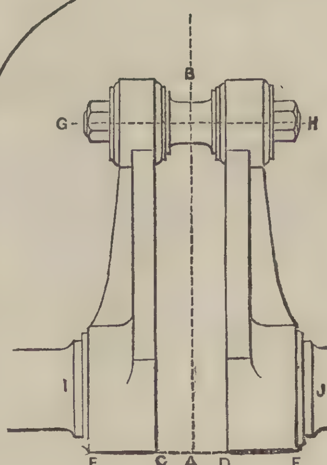


Fig. 216.

for the crank. This will be further elucidated in another lesson.

In the *eccentric* (represented on a larger scale in Fig. 218) a circular plate, A, is surrounded by a hoop, B, the plate being movable about the centre of motion at C.

"The circular eccentric is simply a species of disc or pulley, fixed upon the crank-shaft, or other rotating axis of an engine, in such a manner that the centre or axis of the shaft C shall be at a given distance from the centre of the pulley.

"A ring or hoop, either formed entirely of, or lined with,

"It is evident that as the shaft to which the eccentric is fixed revolves, an alternating rectilinear motion will be impressed upon the rod, its amount being determined by the eccentricity, or distance between the centre of the shaft, C, and that of the exterior circle.

"The *throw* of the eccentric is twice the eccentricity of C F, or it may be expressed as the diameter of the circle described by the point F.

"The nature of the alternating motion generated by the

circular eccentric is identical with that of the crank, which might in many cases be advantageously substituted for it."—*Le Blanc and Armengaud.*

In commencing to draw this example, describe the circles for the hoop, from the centre F. This hoop, which is made in two portions, united by bolts and nuts, is strengthened by flanges, G and G′, the arcs of which are struck from the centres g and g' a little above and below the centre, F.

The end of the shaft, C, and the circles surrounding it, are now to be drawn; then the arm, and subsequently the web, H H. In order to guide the student in joining the curves, the centres of the arcs by which they are united are marked, and he is urged to work with the utmost care and accuracy so that the curves may flow gracefully into each other. The double nuts are next to be drawn.

The fork of the rod is formed by three arcs. The arc I has its centre at i, and this is continued by an arc, K, turning in the opposite direction, drawn from k. The inner arc, J, is struck from j. The rest of the figure will now be easily drawn without further instructions.

Fig. 219.—This figure represents one of the ends of the *valve-rod of a marine engine.* The centres from which all the arcs are drawn are shown, and the whole object being of a very simple form, is left for the student to draw without further aid.

TECHNICAL EDUCATION ON THE CONTINENT.—XI.

BY ELLIS A. DAVIDSON.

THE WORKING MEN'S UNION IN BERLIN—TECHNICAL EDUCATION IN FRANCE.

We now turn to another class of institution, in the carrying out of which working men are associated for intellectual improvement and social intercourse.

The Berlin Working Men's Union, which was established in 1843, attains its object by the following means:—Lectures, conversational lessons, vocal music, gymnastics, lending library, newspapers, social reunions (in which the wives and children of the members are associated). Whilst, however, endeavouring to contribute to the physical and moral welfare of the members, the main object of the Union—intellectual improvement—is anxiously promoted, and this is accomplished by the diffusion of knowledge adapted to the requirements of the various trades, instruction in natural history, by practical lectures on technical art, by personal intercourse with men highly distinguished in the branches of industry on which they lecture, and by special classes for the study of technical drawing and modelling, and of the sciences on which the various trades are based.

MEMBERS.

The Union at the present moment numbers above 3,000 members, who pay a small monthly subscription. The Union does not reject persons who may not be working men; still it has been found that at least nine-tenths of the members are of that class. This circumstance, and the years of travel incumbent upon every German artisan, bring about a frequent change of members; and thus, although the average number on the books at any one period is 3,000, about 10,000 individuals will have been members at some time in the year. The number of persons who have been members of the Union during the previous seven years is estimated at 60,000.

CLUB-HOUSE.

The Union, the operation of which was interrupted by the events of 1848, was reconstructed in 1859, and soon came into such active operation that it became necessary to erect a permanent home for it. The building is large and commodious, containing an assembly or lecture room capable of accommodating 2,000 persons, and thus, with the adjoining garden, opportunities are afforded for recreation in winter or in summer. The class rooms, and those devoted to conversation amongst the members, are all large and comfortable, and the apartments in the basement are devoted to domestic purposes.

MEETINGS AND LECTURES.

The meetings take place on four evenings of the week, and also on Sundays and holidays; they are devoted to lessons, conversation, lectures, etc., on the evenings of the week, and to social intercourse and choral music on Sundays. All the meetings, in fact, begin and close with part-singing. The subjects of the lectures, conversations, and discussions are various, excluding only religion and politics. The lectures are all free to the members, and are given according to a previously published syllabus. From the annual reports of the years from 1861 to 1865, it appears that during that period 592 lectures were given (or about 118 lectures per year), the greater portion of which were devoted to subjects immediately connected with trade, manufactures, and natural history; and here it is again necessary to point out that, in the broad system of German education, the term "natural history" does not merely mean the history of animals, but the science of every section of creation, and that "history" does not mean simply the history of Germany, but *universal* history; so that the student, whilst reading of the events of any particular period in one country, reads also what was occurring in all other known parts of the world. This is a subject as yet very much neglected in our country. At the close of the lectures, the lecturers receive and reply to questions by the members, by which plan an immense amount of information is educed.

TEACHING STAFF.

As in the lectures, the utmost amount of instruction is imparted in the classes by means of questions and answers, and by conversation with the teachers.

The teaching staff is purely an honorary one, not any one of the professors accepting a salary, having taken the self-imposed duty in furtherance of the well-being of the working classes, who, as will be shown presently, avail themselves most gratefully of the opportunities thus held out to them for receiving first-class instruction. The lecturers and teachers are men of the highest metropolitan—in fact, in some cases, European—repute, viz., professors of universities, medical men, architects, engineers, artists, officers of state, managers and proprietors of large works, etc.; whilst the staff of about seventy teachers includes eight members of parliament and seven members of the town council; and the Burgomaster of Berlin is one of the acting board of management. This co-operation of men of the highest position in the scientific, literary, and social circles with the working classes is one which must produce the best results, and which, we are happy to say, is becoming more general in this country than it formerly was.

COURSE OF INSTRUCTION.

The scheme of instruction is designed to improve the incomplete education of members, and to give instruction adapted to the particular requirements of each. The classes are well attended, the subjects of study being—writing and reading; arithmetic; the German language, literature, composition, and correspondence; free-hand and linear drawing; geometry; book-keeping and exchanges; commercial arithmetic; book-keeping by double entry; mechanical and architectural drawing; practical geometry and projection; vocal music; short-hand writing; modelling; the French language; the English language; pattern designing. The following figures show the attendance at some of the classes:—German reading and writing, 144; literature, 45; arithmetic, 60; mathematics, 20; drawing, 101; short-hand, 52; book-keeping, 42; French, 30; English, 15; gymnastics, 150.

ARCHITECTURAL SCHOOL OF THE UNION.

The earnest desire of a great body of the members for further systematic instruction in practical architecture led to the formation of the School of Architecture, under the management of able professors and architects. In this school the students receive theoretical and practical instruction in architecture and the various trades which take their rise from that science. There are four courses of instruction, each extending over four months. The average number of students availing themselves of these advantages is 84.

LIBRARY AND READING-ROOM.

As may be supposed, the library is a most important feature in the institution, affording as it does means for instruction and amusement for the members and their families. Its contents have been acquired partly by gifts and partly by purchase: it is used by about 700 members in the winter and 500 in the summer. The library is open for the exchange of books two evenings in the week. The reading-room is open for the use of members on each evening in the week. The room is supplied

with seventy papers and magazines—political, scientific, literary, artistic, religious, and technical—all of which are gratuitously presented by their respective publishers. The room is very well attended, and is a source of great pleasure and instruction to the members.

It may be interesting now to analyse the number of members, with a view to showing the classes of artisans who have at any time belonged to the Union during the years 1864 and 1865:—

Labourers	633	Various Business Men	1318	Slaughterers	15
Bakers	88	Tinmen	301	Locksmiths	680
Barbers	52	Basket-makers	85	Smiths	273
Public Officers	366	Furriers, Hatters, and Cap-makers	123	Tailors	1118
Coopers	44	Lacquerers	45	Chimney-sweeps	9
Bookbinders	375	House and Decorative Painters	764	Shoemakers	776
Book-printers	132	Fitters	215	Rope-makers	10
Brush-makers	44	Masons and Bricklayers	606	Frame-makers	105
Tilers	20	Mechanics	218	Stamp-cutters	5
Turners	217	Millers	50	Students of Art and Literature	78
Compositors and Printers	321	Needle-makers and Steel-workers	60	Cabinet-makers	2105
Dyers	62	Fringe-makers	104	Potters	78
Tanners	22	Saddlers	195	Watch-makers	87
Glaziers	59	Screen-makers	11	Weavers	1446
Gold and Silver Workers	196			Joiners	388
Belt-makers	193			Total in Two Years	14,152
Glovers	60				

The space at our disposal will not allow of our giving in these papers any further account of the means by which technical education is carried on in Germany; yet all we have described is as a drop in the mighty ocean. The machinery is so vast, and its action so definite, that volumes could be written without exhausting the theme. We leave it, then, unwillingly but of necessity, in order to devote some attention to the

TECHNICAL EDUCATION OF FRANCE.

Our subject not permitting us to enter upon an investigation of the schools for primary instruction, or for the education of the blind, deaf and dumb, or idiots in France, we must pass over all the noble institutions established for these, who have been called the disinherited of Nature.

The improvement in the ordinary means of education provided for children has been deemed by the friends of progress in France to be insufficient to meet the wants of the day. They felt it to be necessary that a great educational system, extensive, varied, and open to all those who wished to learn, should be made available to adults, offering the means of extending the elementary knowledge received in preparatory schools, and providing superior instruction suited to their peculiar avocations. The ministerial orders suggesting lectures and evening schools for apprentices and grown-up people, responded to this double want. Private efforts had, it is true, in this instance preceded official decrees. Several societies had been organised in various places, to provide means for scientific instruction, for the benefit of town workmen. The Polytechnic Association, which dates from 1830, numbers now twenty-two different sections in Paris and its environs; whilst it has founded and endowed a much larger number in various departments, showing that individual enterprise has not been idle. But the effect of an appeal from the Minister of Public Instruction to the intelligence of the country, caused the inauguration of such a vast educational movement, that from the 1st of January, 1864, to the 15th of December, 1866, the number of adult educational institutions was augmented from 5,623 to 28,546, and a spontaneous accession of 600,000 voluntary pupils was thereby created. These institutions have adopted two different methods of instruction, each useful in its way: that of lectures to open the minds of the public, and to enlighten them in various important subjects, and that of absolute lessons for the purpose of affording accurate instruction adapted to the various walks of industry. The education of apprentices and adults, as has been shown in the various programmes already given, when it passes beyond the limits of elementary instruction, changes its character, enters into the arena of applied science and art, becomes, in fact, *technical* education. The recent introduction of the teaching of living languages, commercial geography, and political and industrial economy cannot fail to generalise and constitute for the working classes a superior system of education, by enabling them by the latter to understand and so be satisfied with laws and regulations, of the gist of which they would have otherwise have had no comprehension, and by the former to obtain information from the works published in foreign countries, or in visiting such to be enabled to communicate with others, without the aid of interpreters, who, whilst they may translate the words, cannot translate the spirit, not having a practical knowledge of the subject.

If we except some few departmental centres where public instruction is favourably endowed, the teaching of the applied arts is much better organised than that of the sciences. The practical and successful results achieved by the system of teaching adopted in the drawing and modelling schools, secured for France an honourable position at the London Exhibition in 1862, and this was confirmed by the work shown in the Paris Exhibition in 1867. Paris, which has become so justly celebrated for the production of works of industrial art, has naturally put itself at the head of the movement. By the institution of a certificate of Master or Mistress of Arts as a reward for skilled teachers; the introduction of drawing into the primary schools for girls and boys; the re-organisation of the evening classes for male adults; the opening of lay schools for female adults; annual competitive examinations between classes of the same degree, and the renewal of models according to the rules of the most correct taste, a more enlightened and elevated object is given to instruction. These are great educational advances in which the municipality and the State both participate; and, further, the workmen of France have been made to feel that the traditional fame of their country in industrial and ornamental art will not stand invulnerable against the competition brought about by the increased educational efforts made in other countries; and that if they would hold their own, they must make the strongest efforts with renewed vigour, or they will be compelled to relinquish the palm of superiority. Already the admirable working of the English schools of art has produced an effect on designs and manufactures which is even now turning the pecuniary stream, which has until within recent years flowed to France, into the homes of the English designers and manufacturers; and this healthy competition once established, the English have met with considerable success; whilst they cannot but admit, and gratefully acknowledge, that the very men who are running in the race have helped them in every way. This refers to Germany as well as France, and it may not be out of place to mention here that every information as to systems, details, time tables, etc., of the educational institutions, specimens of the work done in each, copies of the books and examples used, and every possible personal assistance during visits, have been accorded to the writer of these papers by the authorities of the various institutions, and by the working men of all the countries whose educational institutions are herein described.

BUILDING CONSTRUCTION.—XI.

STONE ARCHES—WOODWORK, ETC.

The simplest form of arch—viz., the semicircular—may be considered as the half of a cylinder, and this knowledge will materially assist the student in projecting the different forms now required. The subject of cylinders, their sections and developments, having been fully treated in "Projection" (see Lessons IX. and X., pages 204, 235), it will only be necessary here to apply the principles there laid down.

Let A B D C (Fig. 75) be the plan of a road to be crossed by a bridge, the arch of which is semi-circular. It must, however, at the outset, be explained, that an elliptical or any other form of arch would be projected in an exactly similar manner, the semi-circular being merely chosen in this case as simplest for the present purpose.

Now if the arch were to cross the road at right angles to its sides, A B, C D, the elevation would be that drawn as at E F (Fig. 76), and, of course, any section taken at right angles to the sides would be of the same form, the arch being perfectly semi-circular.

The development of the soffit—that is, the shape of the covering of the interior of the arch—would in that case be a parallelogram, whose width would be equal to the depth of the arch, and whose length would be equal to the curve forming the semicircle E F, and its plan would be the rectangle H I K L.

But, in the present study, the arch crosses *obliquely*, its elevation making an angle of 60° with the side of the road, C D. The plan of the bridge then becomes the rhomboid G H I J, instead of the rectangle H I K L.

The construction necessary for the proper projection of the arch under these circumstances, so as to find its exact shape, is an application of the study given in lessons in "Projection;" for it will be seen that the arch must be treated as a *semi-cylinder*, and the elevation as a section of it at an angle of 60°.

Having drawn the elevation (Fig. 76) as it would be if it crossed at right angles to the roadway, and having divided it into its voussoirs, the joints of which converge to the centre, draw lines perpendicular to E F from the points E, N, O, P, Q, R, S, F, meeting the line at which the arch really crosses in the plan of the arch (and here again the student is referred for elementary information to the figures in "Projection" already mentioned).

Produce the line L H indefinitely, and from the point H, which in Fig. 77 is coincident with E of Fig. 76, set off the lengths N, O, P, Q, R, S, F *from the original elevation*, in order to obtain the length of curve. But the student is reminded that this is only approximately correct, for it is measuring *chords* instead of arcs, and straight lines are, of course, shorter than curves, as a straight line is the shortest distance between any two points. In order, therefore, to approach as nearly as possible to the true length of a curve, it is desirable to divide it into numerous parts, by which the chords become shorter, and the difference between the curved and straight lines is lessened.

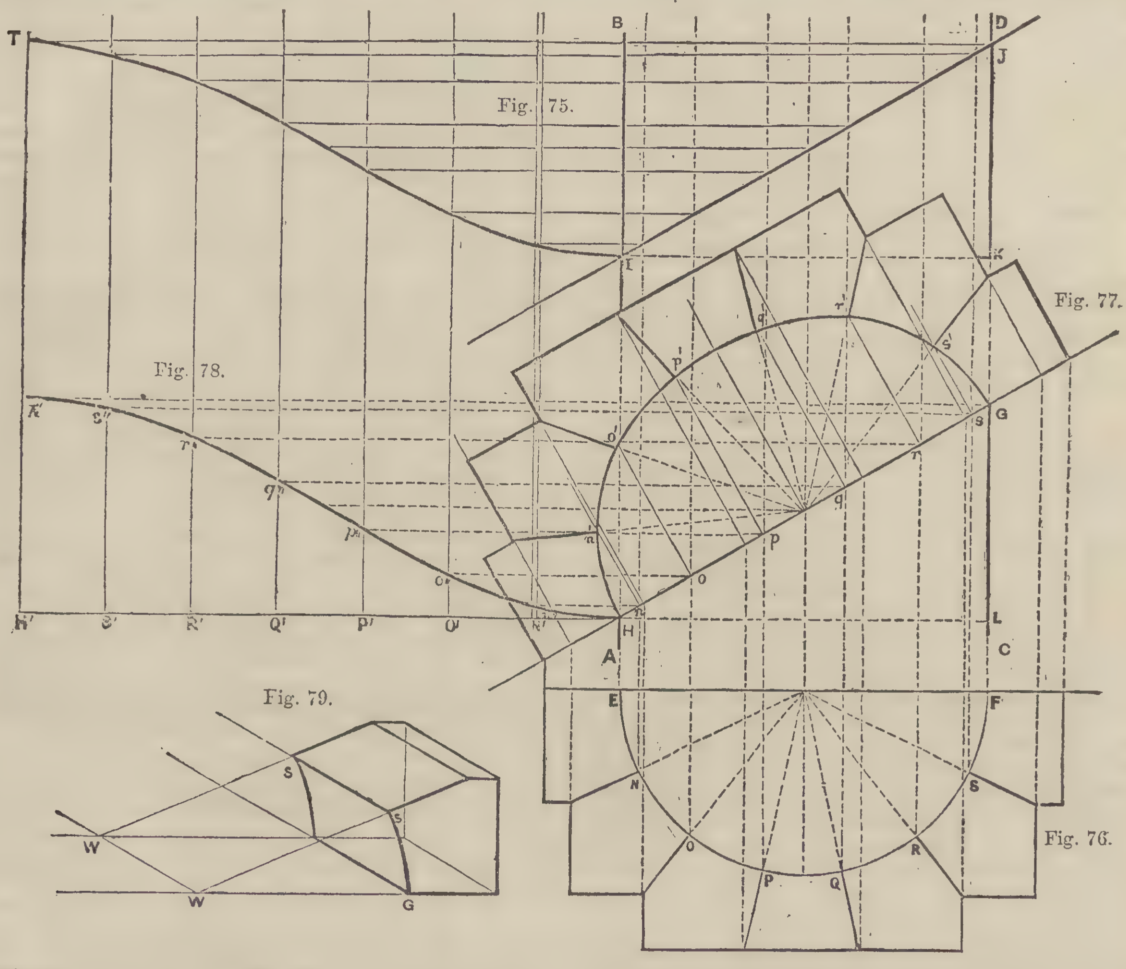


Fig. 75.

Fig. 77.

Fig. 78.

Fig. 79.

Fig. 76.

points H, *n*, *o*, *p*, *q*, *r*, *s*, G (Fig. 77). At these points draw lines perpendicular to H G.

Now the ground line G H (Fig. 77) corresponds with the ground line E F (Fig. 76); it is only longer because it crosses obliquely, and thus the perpendiculars, in consequence of this lengthening of the whole line, will be further apart than they are in the original elevation.

But although they will become further apart they will not be in any way altered in height; therefore mark on the perpendiculars *n*, *o*, *p*, *q*, *r*, *s*, the heights of the perpendiculars N, O, P, Q, R, S in the original elevation (Fig. 76), thus obtaining the points n', o', p', q', r', s'.

The curve drawn through these points will give the true form of the required elevation, and is the shape for the centering on which the arch would be built, and of the templet used in shaping the separate voussoirs.

It will now be convenient, before too many lines crowd the paper, to work out the development of the underneath surface of the arch. Divide, then, one of the spaces—viz., F S—into, say, four equal parts, and set these off from H on L H produced—viz., H H'. Now there are seven divisions in the intrados of the arch, and they are all equal; therefore set off from H the distances N', O', P', Q', R', S', H' equal to F S. The length H H' is thus the length of the curve.

From N', O', P', Q', R', S', H' erect perpendiculars, and intersect them by horizontals drawn from the points similarly lettered in the base line of the oblique elevation.

Through the points thus obtained—viz., n'', o'', p'', q'', r'', s'', h''—draw the curve H h'', and from them set off on the perpendiculars the lengths H I. Connect these points by the curve I T, and the figure H I T h'' (Fig. 78) will be the development of the soffit of the arch.

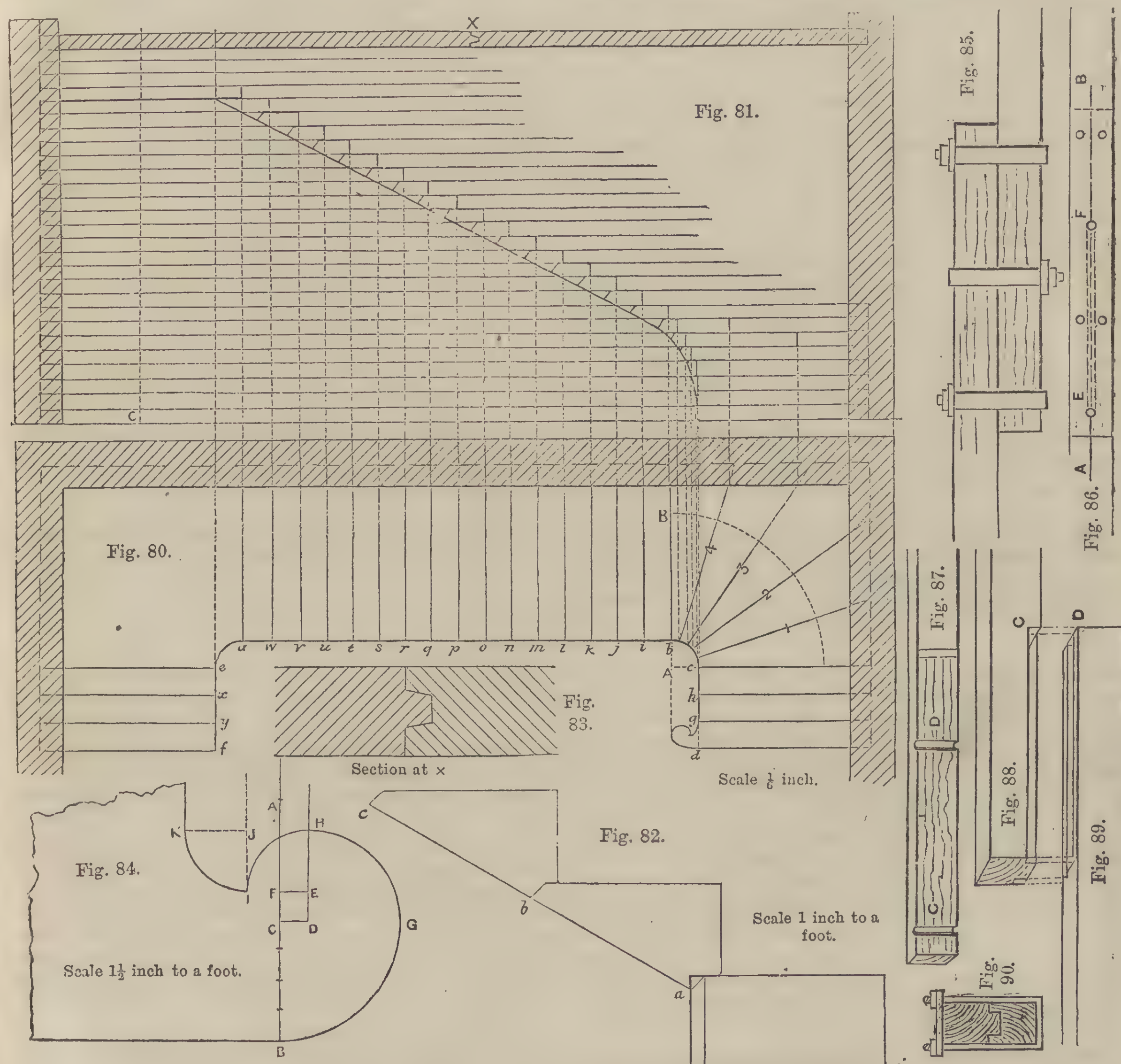
To draw the outer edges of the voussoirs, proceed, precisely as before, to draw lines parallel to the axis of the cylinder, and at the points where such lines meet the base line of the oblique elevation, draw perpendiculars to G H. Mark on each of these

the heights taken from the base line in the original elevation, and the rest will be seen from the diagram.

Fig. 79 shows a simple projection of one of the voussoirs, the first on the left side. The face is, of course, drawn from the oblique elevation, the curve being struck from the templet already mentioned, which may for drawing purposes be cut out of a piece of veneer. If this is done, the student will easily be able to draw the portion of the curve required for each voussoir.

one is divided into five stairs called *winders*, whilst the straight stairs are called *flyers*.

To draw the winders, produce the lines forming the edges of the steps *b* and *c*, until they meet in A. Then from A, with radius A *b*, describe the quadrant connecting the lines *d c* and *a b*. The same radius will also give the quadrant at the opposite end. From A with any radius describe the quadrant B, and divide it into five equal parts; through these points draw lines converging to A, which will complete the plan of the winders.



Produce the base and the slanting portion of the face until they meet in W. This wedge form will then correspond with that in the oblique elevation produced to the centre.

With the set-square of 30° draw the receding lines, and it will be evident that the distant edges are parallel to those in the front.

Fig. 80 gives the plan, and Fig. 81 the elevation, of a stone staircase, with detail to an enlarged scale.

Draw the walls of the plan, and from the inside lines of these draw the lines *a*, *b*, *c*, *d*, and *e*, *f*, equal to length of the steps from end to end. Mark off on these the *widths* of the steps, and draw the lines which will be the plans of the edges *d*, *g*, *h*, *c*; *b*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v*, *w*, *a*; *e*, *x*, *y*, *f*. The quarter-spaces will still be left in the corners, and of these the

In the other corner there is really a quarter-space, and from this four steps rise, the last of which is the landing.

It will be seen that the steps are built into the wall. This is shown by the dotted lines in the plan. The lowest one also rests on the ground, and this supports the length of the one above it, and so on in succession, the stairs fitting in to each other by a joint called a "joggle," shown at *a*, *b*, and *c* in Fig. 82.

It is necessary here to mention that the flat surface of a stair is called the *tread*, and the upright face is termed the *rise*.

The slabs forming the passage seen in section in the elevation at X (Fig. 81) are joined as shown in Fig. 83. They, too, are built into the wall at their inner edge, and the passage is further supported by a cantaliver, not shown in this elevation.

Fig. 84 shows the mode of describing the curtail, or lowest step, drawn to the scale of $1\frac{1}{2}$ inch to the foot.

Draw A B equal to the width of the visible portion of the tread of the step—namely, eleven inches by scale, an inch and a half being covered by the step above.

Bisect A B in C, and divide C B into four equal parts. On the bisecting line C construct the square C D E F, the sides of which equal any one of these four parts.

From C, with radius C B, describe the quadrant B G. From D, with radius D G, describe the quadrant G H; and from E the quadrant H I, which will complete the spiral.

From I draw a perpendicular, and make I J equal to I E. From J, with radius J I, describe the quadrant I K, and from K the straight end of the step will be drawn as shown in the general plan. The projection of the elevation of the steps is so simple that it will not require much explanation.

Having projected from the plan the mere sections of the walls supposed to be cut through, draw any perpendicular, as C, and on it set off the heights of the rises. This height is, of course, regulated by the room at the disposal of the architect, and the height of the floor to be reached: in this case an average height of rise is taken—that of six inches.

Letter each of these points to correspond exactly with the figuring of the edges of the steps on the plan. (It will be seen that, in order to avoid crowding, figures belonging to the winders are placed on the lines, instead of at their extremities.)

Now from the points marked in the perpendicular in the elevation draw horizontals, and from the points at the extremities of the edges of the steps in the plan draw perpendiculars; then the right angles formed by the intersections of the lines similarly lettered will be the end elevations of the stairs. All other guidance may be obtained by careful study of the diagrams.

WOODWORK: DRAWING FOR CARPENTERS AND JOINERS.

JOINTS IN TIMBER.

Before treating of what are usually termed joints, we must give some attention to the methods of uniting pieces of timber so as to increase their length, whilst achieving, as nearly as possible, the same amount of strength which the timber would have if it consisted of one piece only.

In writing on this subject, the author necessarily bases his observations on the principles laid down by such standard authorities as Tredgold, Robison, Thomas Young, Peter Nicholson, etc.; but he has also been guided in some degree by German and French practice. Some of the examples are culled from Continental sources, in order to give the student as extended a view of the subject as the limits of these lessons admit; and to the information thus gleaned he has added the results of his own experience, extending over many years.

The modes of joining timbers, so as to increase their length, are very numerous, and have most of them certain advantages when applied under particular circumstances. Some of the methods adopted are ingenious, but the simplest is generally the best. It will be clear that the method of joining shown in Fig. 85 must be the strongest that could possibly be adopted. Here two pieces of the same scantling* are laid over each other for a certain length, and then either held together by iron bolts or by bands. The author prefers the latter, because, by boring holes through the timber, the fibres are divided, and the strength of the beam thereby diminished. This, it is hoped, will be made clear by the following diagram.

Let us suppose ourselves looking down on a beam united as proposed, by placing the ends one over the other and bolting them together. Our view then would be that represented in Fig. 86.

Fig. 87 shows the section of the lower timber on the line A B, as it would be if bored for bolts, and in this it will be seen that the fibres are totally severed at C and D, and that the wood between the two bolt-holes cannot in any way contribute to the strength of the beam as far as its *length* is concerned, as it is only connected with it by its lateral cohesion.

* *Scantling.*—The transverse dimensions of a piece of timber in breadth and thickness. Scantling is also the name of a piece of timber, as of quartering for a partition, or the rafter, pole-plate, or purlin of a roof. All quartering (the small timbers of which partitions are built) under five inches square is called *scantling.*

This being understood, we return to the plan (Fig. 86), and here we shall see that, as the connection between the fibres at E and F has been severed by the bolts, the whole of the strip between them (shown in dotted lines) is rendered useless; and as this occurs three times in the beam, the only parts left in their natural strength are those not pierced by the bolts; and *these are not fastened together at all.* It is therefore necessary that iron plates should be placed over the parts to be joined, and by this means the whole may be held firmly together.

Now the system proposed by the author for joining beams of great length is shown in the following diagrams.

Figs. 88 and 89 show how a rebate is to be sunk in the one beam and a tongue left in the other. This form leaves a shoulder at C, against which the end D presses, thus affording security against compression from the ends, and preventing all chance of the beams sliding over each other.

Fig. 90 is a section showing the iron strap which forms three sides of a rectangle, the fourth being formed by a plate, which fits in the screws at the ends of the strap, and is secured by nuts. This allows of occasional tightening-up, if there should be any sagging owing to shrinking of the wood, etc.

CHEMISTRY APPLIED TO THE ARTS.—VII.

BY GEORGE GLADSTONE, F.C.S.

SODA.

SODIUM (chemical symbol Na, from the Latin word *Natrium*), which is the metallic base of soda, is one of the commonest substances in Nature; though it never occurs as a metal, because it immediately takes fire in the air, in consequence of its great affinity for the oxygen of the atmosphere.

What is most generally known as soda is a compound with carbonic acid. Another most familiar combination is that with chlorine, forming the common table salt. A third, which is not uncommon in Nature, and which is also largely manufactured, is produced by sulphuric acid, forming sulphate of soda, or Glauber's salts. The other preparations of soda are of minor importance.

It is the carbonate of sodium (Na_2CO_3) with which we are specially to concern ourselves, as it is manufactured on a very extensive scale, employing a large number of hands, and contributing greatly to the prosperity of certain districts in England and Scotland. The borders of the river Tyne, below Newcastle, may be considered the head-quarters of the manufacture in England, though there are also some large works near Liverpool. In Scotland the principal establishments are situated in the neighbourhood of Glasgow.

Great changes have taken place in this branch of trade, and many of the sources of supply which were much valued formerly are now comparatively neglected. The plants which thrive on the sea-beach used to be collected and burnt for this purpose, as their ash contains a considerable per-centage of soda; and some kinds of sea-weed are also treated in the same way. In addition to the home supply from our own coasts, it used to be imported from France, Spain, the Canary Islands, and other places, under the name of *barilla.* It is now, however, made almost exclusively from other articles, very different in their character, and which can be obtained in almost unlimited quantities.

Common salt, sulphur, limestone, and coal are now the principal ingredients; and all these are, fortunately, very abundant in Nature. The sulphur is by far the most expensive, as it has for the most part to be imported from abroad, but the sources from whence it is obtained are multiplying so rapidly that the manufacturers can depend upon a regular supply at a much more reasonable price than formerly. Until very recently, the sulphur used in this country came almost exclusively from Sicily, and the supply with difficulty kept pace with the increasing demand. This led to the substitution of pyrites, a mineral consisting of sulphuret of iron or copper, the price of which was so much lower as to be more economical. Pyrites are now brought in very large quantities from Ireland, Spain, Portugal, and Norway, to Newcastle, Liverpool, and Glasgow, in order to furnish the great chemical works at these places with this necessary ingredient.

Common salt (the chloride of sodium) is the article from

which the soda of commerce is made. The first step is to convert it from a chloride to a sulphate. This may be done by roasting the salt in a furnace, along with sulphuric acid, by which means the chlorine is driven off and the sulphur takes its place. For this purpose a reverberatory furnace is used, fitted with shallow pans lined with lead, into which the salt and acid are put, and over which the fire from the furnace passes. The pans are charged with equal weights of salt and sulphuric acid of specific gravity 1·45, which are well mixed up by means of a rake, and then the door is closed and the furnace heated. About an hour's roasting will suffice to convert the salt into the sulphate of soda, so that the same furnace will serve for several charges in the course of the day, turning out 9½ tons of the sulphate to every 8 tons of salt. During this process the chlorine has been driven off, but the manufacturer cannot allow it to escape into the atmosphere by the chimney, because, in the first place, it is of value, and, in the second, it would be a serious nuisance to all his neighbours; the gas, therefore, is made to pass through condensers—high chambers, through which a shower of water is continually falling; the water absorbs the gas as it rises from below, and forms hydrochloric acid. The furnace is often arranged with a lofty chamber or tower between it and the condenser, in which limestone or baryta is placed, for the purpose of absorbing a part of the chlorine, and producing chloride of lime or barium, as the case may be; the former being used as bleaching powder, and the latter as a white paint. By these various means scarcely any of the chlorine is lost, and the profits of the soda manufacturer are considerably enhanced.

The sulphate of soda has now to be converted into the carbonate. For this purpose it is roasted with about an equal quantity by weight of carbonate of lime, and one-half its weight of coal, in a reverberatory furnace. These substances are generally broken up small, and well mixed together, and as soon as the furnace is heated to a bright red heat the charge is gradually introduced into the first compartment of the furnace. As soon as it has been sufficiently heated through, it is transferred to the second, where it is subjected to a higher temperature, and forms a soft doughy mass, which is kept well worked by means of long iron stirrers. During this process the mass evolves carbonic acid, and as soon as the gas has all passed off, and the contents of the furnace assume a tranquil liquid condition, they are raked out of the furnace and allowed to cool. The substance which results from this treatment is commonly called *ball soda.*

It will be seen from this description that a considerable amount of manual labour is necessary at this stage of the process; and the success of the operation greatly depends upon the charge being well worked by the stirrers while it is in the furnace—very hot and laborious work. A very interesting arrangement is adopted in some of the best alkali works, in order to avoid the stirring altogether. The furnace itself is made to rotate, and as it turns the ingredients become thoroughly and uniformly mixed. The part which receives the charge consists of a long iron drum, turning horizontally upon its axis—the flue passing through the two axes—and having a door in the circumference, which serves both for charging and discharging it, according as it is brought to the uppermost or lowermost part of its circuit. The charge passes in through a hopper, the aperture is closed, and the furnace is made to revolve. When the roasting is complete, the door is opened, and the charge passes out into receivers placed below.

The *ball soda* thus prepared consists of porous lumps, of a dirty grey colour, composed principally of carbonate of sodium, sulphide and carbonate of calcium, and carbon. This, when reduced to powder, is sold, and exported in considerable quantities, under the name of *black ash.* The balls will fall to pieces of themselves by merely damping them with water and exposing them to a high temperature.

Carbonate of sodium is very readily soluble in water at any temperature, though hot water will take up much more than cold. Advantage is taken of this circumstance in order to separate the carbonate of sodium from the other ingredients contained in the ash. A series of cisterns, each one at a slightly lower level than the preceding, are therefore filled with the *black ash,* and water is made to pass gradually through them, taking up more and more of the soda as it passes along, until it is fully saturated, and the ash is quite exhausted. It is generally found convenient to keep the water at a temperature of something over 100° Fahrenheit.

Having thus obtained an aqueous solution, the water has to be evaporated, so as to separate the soda in a solid state. The evaporation of so large a bulk of water involves the expenditure of a great amount of heat, so that, as a matter of economy, the waste heat as it passes from the balling furnaces is ordinarily made to serve this purpose. Various forms of evaporating pans or troughs are used, and in some works the crystals as they form are raked out by manual labour, while in others machinery is adopted for this purpose. The soda thus obtained contains generally about 70 per cent. of carbonate, 15 per cent. of the hydrate, and 6 per cent. of the sulphate.

In order to free the carbonate from the other compounds, the ash is again heated in a reverberatory furnace, with a little sawdust or small coal. Care must be taken not to heat it so highly as to cause the ash to fuse, which would entirely defeat the object; and during the process the ash must be kept well stirred. By this means the sulphur is driven off, and at the same time the excess of carbon, after having converted both the sulphate and caustic soda into the carbonate.

If *white alkali* be required, the soda, after coming out of the carbonating furnaces, is again dissolved by means of steam, and then allowed to crystallise out on cooling. In this state soda is used in various manufactures, such as in soap-boiling and plate-glass making. For other purposes, however, it must be still further purified.

To produce what are commonly known as *soda crystals,* the white alkali is again dissolved in boiling water, and then either filtered or transferred to iron tanks, where the liquor is left to settle for about twelve hours. If necessary, the latter operation is repeated a second time, and a little lime is added, to assist in throwing down the remaining impurities. It is boiled until it attains a specific gravity of 1·3, and then left to stand until the temperature falls to 92° Fahrenheit, when it is run out into large cooling-pans to crystallise. Upon the surface of the liquor in these pans bars of wood are placed, which constitute a nucleus for the formation of the crystals. Attaching themselves in the first instance to the wood, they grow downwards into the liquor, forming beautiful masses of large pointed crystals. In the course of from five to ten days, according to the season of the year, the liquor is exhausted as far as is possible by this means, and being drawn off, it is evaporated down, so as to preserve the residue, which forms an inferior white alkali. The soda crystals are almost pure carbonate of sodium, with ten equivalents of water of crystallisation ($Na_2CO_3 + 10H_2O$); or, in round numbers, about 37 per cent. of carbonate of sodium and 63 per cent. of water. This is as pure as it can be made in such large quantities as are required in commerce, and, accordingly, the description of the manufacture of the carbonate of sodium stops at this point.

Caustic soda is also made now on a considerable scale at the chemical works, as there is an increasing demand for it on the part of bleachers and soap-boilers. It is the hydrate of sodium ($NaHO$), and is made from the black ash, or soda ash, already described, by dissolving it in sufficient water to produce a liquor of a specific gravity of about 1·1, which is then put into a large vessel, and stirred actively while lime-water is being gradually added to it. After about half an hour it is left at rest, the decomposition having been completed; and the lime, having taken up the carbonic acid of the soda, is gradually deposited in the condition of carbonate of lime at the bottom of the receiver. The soda liquors, being drawn off into boilers, are then concentrated, during the several stages of which process the sulphate, chloride, and other impurities crystallise out, and are removed by perforated ladles. The remaining liquor is finally boiled down until it is thoroughly concentrated, and is then left to cool, when it becomes solid. For some purposes the caustic soda is sold in the liquid state; and in this case the boiling is stopped when the solution has been raised to a specific gravity of about 1·35, at which strength it retains its liquid condition on cooling. This is commonly called *soaper's lye.*

Bicarbonate of sodium, or the acid carbonate ($NaHCO_3$), may be prepared from the neutral carbonate already described, by filling a chamber with the soda crystals, and then passing carbonic acid gas through it. The gas may be generated by decomposing chalk or limestone (carbonate of lime) with

hydrochloric acid, the chlorine combining with the lime and freeing the carbonic acid. In the course of ten to fourteen days' exposure to the action of this gas, the soda crystals will have taken up a second equivalent of carbonic acid, and thus have become a bicarbonate. It will be seen, by a comparison of the chemical formulæ, that the relative proportion of the carbonic acid to the soda is double that given above for the carbonate of sodium. The bicarbonate is then gently heated for the purpose of drying it, and ground to a fine powder. Care must be taken not to make it too hot, or the carbonic acid will be driven off again, and it will be reduced to a carbonate.

Soda-works must always be situated in places where salt, sulphur, limestone, and coal can be obtained on favourable terms, and also where there is plenty of waste land for depositing the refuse. The quantity of this is so great that large mounds of it are always to be seen in the neighbourhood of the works, and it would be greatly to the advantage of the trade if a means of utilising it could be found.

The pyrites, now so largely used, consist of the sulphurets of iron and copper, and the latter metal is frequently in sufficient quantity to be worth extracting. Copper-works are accordingly rising side by side with the soda-works, and are usually carried on in conjunction with the latter, no less than 7,600 tons of copper having been made in 1869 from the pyrites used in the manufacture of soda. This represents one-eighth of the whole quantity of copper smelted annually in this country, and furnishes one instance amongst many of how one industry reacts upon another.

PRACTICAL PERSPECTIVE.—II.

FIG. 7.—The object of this illustration is to show that *all lines which in Nature are at right angles to the plane of the picture must in the drawing converge to the centre of vision.*

But little argument will be required to convince the student of this. He will have noticed how the metals on a railway seem to meet in the distance, and how the two sides of the pavement of a long street converge: he can, in fact, scarcely cast his eye around without being impressed with this fact.

Fig. 8.—It will be clear then, that as a line which is at right angles to the plane of the picture is drawn to the centre of vision, any *point* which moves away from us, in a straight line from the foreground to the distance, will travel in such a line.

The student who has followed the course laid down in other lessons in this work, will have learnt how to construct scales of different proportions; but to others it will be necessary to explain, that as but few objects are drawn of their real size, a method is adopted by which their different parts, etc., shall be kept in a certain proportion to those of the object itself; this is called "drawing to a given scale."

Thus, if it is said that an object is drawn to the scale of "1 inch to the foot," it is meant that whatever is 1 *foot* long in the object is represented by 1 *inch* in the drawing, and thus the representation will be *one-twelfth* of the real size.

Now in Fig. 8 the scale adopted is $\frac{1}{8}$ of an inch to the foot.

The eye of the spectator is supposed to be 5 feet above the ground, and 11 feet distant from the picture. To represent this—

Draw the picture-line, P L, and the horizontal line, H L, at 5 feet (that is, $\frac{5}{8}$ of an inch) above it.

Place the centre of vision, C, anywhere (in this case) on the horizontal line.

The spectator is to be 11 feet distant; therefore set off 11 feet on each side of C, and the points of distance, P D, will be thus obtained.

Now let it be required to find the perspective position of a point, which is 9 feet on the left side of the spectator, and 2 feet back; or as it is called, 2 feet *within* the picture.

Whenever a point in the distance is to be found, it is necessary, in the first instance, to ascertain its exact place in the foreground; thus, having drawn the perpendicular, C A, set off from A, 9 feet along the picture-line; then A′ is the position of the point at 9 feet on the left of the spectator; but as yet it is in the *foreground*, not back in the picture.

Now it will be clear, that as this point moves directly backward, it will travel in a line at right angles to the picture-line, and that such a line will vanish in the centre of vision.

Therefore, from A′ draw a line to C, which will be the perspective representation of a line running directly backward into the distance.

But it is required that the point in question shall be not only 9 feet on the left of the spectator, but 2 feet *within the picture*.

To find its position, then, set off 2 feet on the right of A′—viz., point 2; and from 2 draw a line to the point of distance, P D.

Then 2′ will be the required position of the point—viz., 9 feet on the left of the spectator, and 2 feet within the picture.

Now let it be required to find the perspective position of a point which is 9 feet on the left of the spectator and *four* feet within the picture.

This is simply the same point, which is supposed to have travelled 2 feet farther back; therefore, from A′ set off point 4 (that is, *two* feet added to the former 2), and draw a line from 4 to the point of distance; then 4′ will be the perspective position of the point.

Proceed in the same manner to find the position of the same point when it has travelled 6 and 8 feet backward, and thus obtain points 6′ and 8′.

Fig. 9.—Now let it be required to find the position and apparent height of a perpendicular, the *real* height of which is 12 feet, when it stands at 9 feet on the right of the spectator, and 2 feet within the picture.

At B, 9 feet on the right of A, draw a perpendicular, B D, 12 feet high by scale; and from the top and bottom of it draw lines to the centre of vision. This would represent a *wall* or *plane* extending from the foreground into the distance.

Now it is clear that the required perpendicular will be somewhere in this plane; the question is, *where?*

This is solved by the application of the last study. Set off from B 2 feet along the picture-line—viz., point 2; from 2 draw a line to the point of distance, and this line, cutting B C in 2′, will give the position of the line.

At 2′ draw a perpendicular meeting the line D C, and this will be the line required—which, it will be observed, has diminished, because it is a little distance back in the picture.

Proceed in the same manner to find the position of the same perpendicular when it is at 4, 6, and 8 feet within the picture.

EXERCISE 1.

The height of the spectator is 6 feet, the scale being $\frac{1}{8}$ of an inch to the foot; the distance of the eye is 13 feet.

Find the positions of the following points:—

(1.) 11 feet on the right of the spectator, and 3 feet within the picture.

(2.) 8 feet on the right of the spectator, and 6 feet within the picture.

(3.) 10 feet on the left of the spectator, and 7 feet within the picture.

(4.) 3 feet on the left of the spectator, and 12 feet within the picture.

EXERCISE 2.

The spectator is 5 feet high, and 15 feet distant from the picture.

Find the position and perspective heights of the following perpendiculars:—

(1.) 8 feet on the left of the spectator, 10 feet high, and 3 feet within the picture.

(2.) 12 feet on the left of the spectator, 11 feet high, and 6 feet within the picture.

(3.) 13 feet on the right of the spectator, 12 feet high, and 10 feet within the picture.

(4.) 11 feet on the right of the spectator, 4 feet high, and 8 feet within the picture.

Now this study will show the method of solving a question which has often been given in examinations—namely, that of finding the position of a bird flying at a certain distance from the spectator, and at a given height.

Let us suppose the measurements to be these:—Distance on right of spectator, 9 feet; height from ground, 12 feet; distance back in the picture, 20 feet.

Now it will be clear to the student that if a bird flying held in its talons a line with a weight at its end, such line would be a true perpendicular to the ground, the bird being at its upper extremity, and thus the whole question resolves itself into this: Put into perspective a perpendicular 9 feet on the right of the spectator, 12 feet high, and 2 feet within the picture.

To do this we simply return to Fig. 9.

Here we have already drawn a perpendicular, B D, at 9 feet on

the right of the spectator, and 12 feet high, and we have drawn lines from its extremities to C.

It now only remains to set off 20 feet along the picture-line from B, namely, B 20, and from 20 draw a line to the point of distance. This will give the point *b*, which is the position of the perpendicular to be drawn on *b* to meet D C in *c*.

Then *c* is the position of the bird, as required.

Fig. 10.—It is not necessary in every case to show both the points of distance; thus, as in this study—a line on the right side of the spectator—we can dispense with the left-hand point of distance. Here the height of the eye of the spectator is 6 feet ($\frac{1}{6}$ scale), and his distance 16 feet.

The subject of this study is a line which lies at right angles to the plane of the picture, at 12 feet on the right of the spectator, and 4 feet back in the picture, the length of the line itself being 6 feet.

From A, the point immediately under the centre of vision, set off 12 feet, namely, to B, and draw a line to C.

From B, towards A, set off 4 feet, namely, to C′, and draw a line to the point of distance. This will give the point *c*.

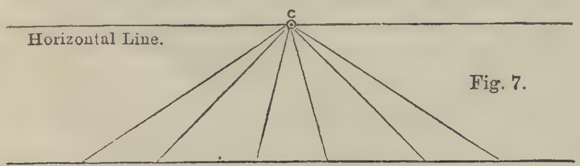


Fig. 7.

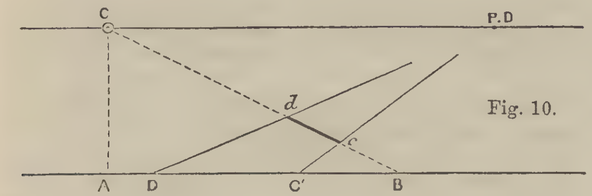
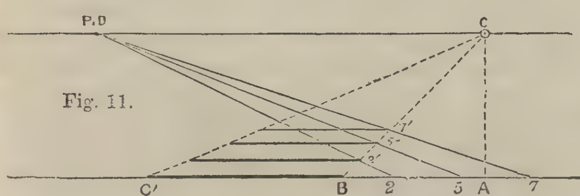


Fig. 10.



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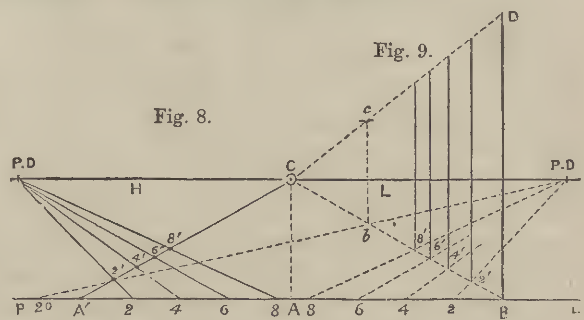


Fig. 8. Fig. 9.

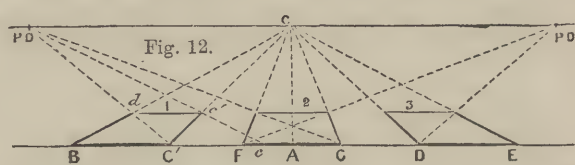


Fig. 12.

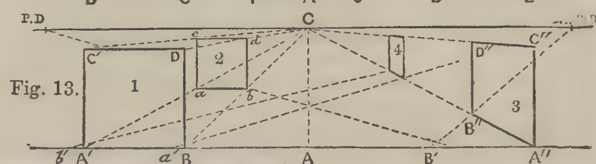


Fig. 13.

From C′ set off 6 feet on the picture-line, namely, to D, and draw a line from D to the point of distance, cutting B C in *d*.

Join *c d*, and this will represent the line in the perspective position required.

EXERCISE 3.

The height of the spectator is 5 feet, and his distance 15 feet (scale, $\frac{1}{4}$ inch to the foot).

Give the perspective projections of the following lines, lying at right angles to the picture-plane :—

(1.) 7 feet long, at 10 feet on the left of the spectator, and 2 feet within the picture.

(2.) 9 feet long, 6 feet on the left of the spectator, and 4 feet within the picture.

(3.) 10 feet long, 7 feet on the right of the spectator, and 6 feet within the picture.

(4.) 8 feet long, 6 feet on the right of the spectator, and 2 feet within the picture.

Fig. 11.—The scale in this study is $\frac{1}{6}$ of an inch to the foot. The height of the spectator is 6 feet, the distance 16 feet.

Here a line, B C′, 8 feet long, lies in the immediate foreground, the end B being 6 feet on the left of the spectator.

It is required to put this line into perspective when lying at 2, 5, and 7 feet within the picture.

From B and C′ draw lines to the centre of vision, and as the line B C′ is to travel backward, but remain parallel to the picture-line, it must, however it may change position, be contained between these two lines. Now from B mark off B 2, B 5, and B 7, representing the distances at which the line is to be placed. From each of these points draw lines to the point of distance, cutting B C in 2′, 5′, and 7′.

From these points draw lines parallel to C′ B, and contained between B C and C′ C. These will be the perspective representations of the line C′ B at the distances of 2, 5, and 7 feet within the picture.

EXERCISE 4.

Scale $\frac{1}{2}$ inch to the foot. Height of the spectator, 6 feet; and his distance, 15 feet.

Put into perspective a line 6 feet long, when lying parallel to the picture-plane, at the following distances :—

(1.) When one end is at 3 feet on the left of the spectator, and the line is 4 feet within the picture.

(2.) When one end is at 4 feet on the right of the spectator, and the line is at 10 feet back.

Fig. 12 shows three squares, (1), (2), (3), lying flat on the ground, their front and back lines being parallel to the plane of the picture, and their sides at right angles to it.

Here the eye of the spectator is 5 feet above the ground (or picture) line, and the distance is 11 feet ($\frac{1}{8}$ scale).

The sides of the squares are 4 feet, C′ and D are 5 feet on the left and right of the spectator, whilst F G is immediately in front.

Having drawn lines from B, C′; F, G; and D, E to the centre of vision, between which the squares must be contained, the next question is how to find the place for the back line of each.

The general method of finding the position of a horizontal line at any given distance has been shown in the last figure, and this could be applied in the present study—namely, by setting off from C′ the distance *c*, equal to the length of the required side of the square, and drawing from *c* a line to the point of distance. This would be the method to be pursued for any rectangle; but for a square an easier method can be found, by which the trouble of marking the point *c* can be saved—namely, by drawing a line from C′ to the point of distance, which, by cutting B C in *d*, will give a point immediately opposite to C′, and a horizontal line drawn from this point will complete the figure.

This is again shown in Fig. 12 (2), (3). It is not really necessary in (2) to draw a line to each of the points of distance, but in early studies it is best to do so as an additional test of accuracy.

EXERCISE 5.

Scale $\frac{1}{2}$ inch to the foot. Height of spectator, 6 feet; and distance of spectator, 16 feet.

Put into perspective three squares lying flat on the ground with their front and distant edges parallel to the plane of the picture.

(1.) 3 feet side, immediately in front of the spectator and in the foreground.

(2.) 4 feet side, at 5 feet on the left of the spectator, and 8 feet within the picture.

(3.) 2′ 6″ (2 feet 6 inches) side when lying at 6 feet on the right of the spectator, and 9 feet within the picture.

For Fig. 13, the height and distance of the spectator are the same as in the last figure (Fig. 12).

Fig. 13 (1) is a square of 4 feet side, standing on one of its edges, its surface being parallel to the picture-plane, and its nearest angle, B, being 5 feet on the left of the spectator.

As there will be no difficulty in constructing this original square, A′ B D C′, we can therefore at once proceed to find its position and size when removed 11 feet within the picture.

From A′ and B draw lines to the centre of vision. From B set off on the picture-line the length B′ (11 feet), and from that point draw a line to the point of distance, cutting B C in *b*.

At *b* draw the horizontal line *b a*, which will be the base of the square at the required distance. Now, knowing the figure to be a square parallel to the plane of the picture, we could easily complete this study by constructing a square on *a b*, as in Fig. 13 (2). But this method would apply to a square only, and if any other parallelogram were required, we should have to obtain the size by the following process :—

At *a* and *b* erect perpendiculars of *any* height (temporarily). Draw lines from the upper angles C′ and D of the square or other parallelogram to the centre of the picture; then these, cutting the distant perpendiculars, will give the points *c*, *d*; and these joined will complete the square at the required distance.

EXERCISE 6.

Scale, ½ inch to the foot; height of spectator, 6 feet; distance 18 feet.

Put into perspective a square of 9 feet side, when standing with its surface parallel to the picture-plane.

(1.) When in the foreground, at 7 feet on the left of the spectator.

(2.) When at 5 feet on the left of the spectator, and 10 feet within the picture.

Fig. 13 (3).—In this study the square is rotated on the line A″ C,″ so that its surface is at right angles to the picture-plane.

Having erected the perpendicular A″ C″, at (say) 9 feet on the right of the spectator, draw lines from its extremes to the centre of vision. From A″ mark off on the picture-line the length A″ B′ equal to the side of the square; and from B′ draw a line to the point of distance. This, cutting the line A″ C in B″, will give the point for the distant edge B″ D″ of the square.

Fig. 13 (4) is the same figure removed to 15 feet within the picture. As the working is shown, and as the method is similar to what has already been done, it is hoped that the student will be able to obtain the required result without further instructions.

EXERCISE 7.

Scale ½ inch to the foot; height of spectator, 5 feet; distance, 15 feet.

Put into perspective the squares, the dimensions of which are given below, when standing at the stated distances; the plane (or surface) of the square *to be in every case at right angles to the picture-plane.*

(1.) 3 feet side, at 2 feet on the left of the spectator.

(2.) 8 feet side, at 7 feet on the left of the spectator, and 6 feet within the picture.

(3.) 4 feet side, at 3 feet on the right of the spectator, and 2 feet within the picture.

(4.) 7 feet side, at 9 feet on the right of the spectator, and 6 feet within the picture.

WEAPONS OF WAR.—VI.

BY AN OFFICER OF THE ROYAL ARTILLERY.

BREECH-LOADING SMALL ARMS (*continued*).

IN a former paper we have treated of the transition from muzzle-loading to breech-loading rifles for military use, and have shown how this was accomplished in our own service, by the simple and satisfactory expedient of fitting the Enfield rifle with an arrangement which admitted of its being loaded at the breech, and providing it with a suitable and ingenious breech-loading cartridge. The combination gives us an arm about equal to the old Enfield rifle in shooting power, but more destructive, in consequence of the employment of a hollow bullet, and capable of greatly increased rapidity of fire. But it was clear that we had not here the final and complete solution of the question. The shooting power of the old Enfield is not of a sufficiently high character to satisfy the requirements of the present age. Since 1853, when this weapon was introduced, vast strides have been made in arms of precision; and the Enfield rifle is now unable to hold its own against the small-bore rifles which surpass it in accuracy, range, flatness of trajectory, penetrative power, and other valuable qualities. So also with regard to the breech action: many minds have been at work on this question for several years, and the result is that there exist several breech mechanisms which are as superior to the Snider as the small-bore rifle is superior to the large bore.

Therefore, it became a recognised necessity for the military authorities to look beyond their converted Snider-Enfields to a new arm for future manufacture. It would occupy too much space if we were to attempt to describe the steps and experiments which have finally resulted in the adoption of a composite arm—the Martini-Henry rifle. This arm has the form of barrel designed by Mr. Alexander Henry, of Edinburgh—viz., a polygonal barrel, the angles of which are broken by ribs which create re-entering angles, the inscribing circle tangential to the ribs being described with the same radius as the inscribing circle tangential to the plane sides. The twist of rifling is 1 turn in 22 inches. The calibre is ·45 inch. Admirable results have been obtained with these barrels, which are now very generally adopted by military rifle-makers, who fit on to them different breech-actions, according to their fancy. The initial velocity of the rifle, with a charge of 85 grains, is about 1,365 feet per second, against 1,250 for the Snider; this, taken in conjunction with the fact that the bullets are of the same weight (480 grains), but that the Henry bullet is of less diameter than that of the Snider, results in a considerably flatter trajectory on the part of the Henry bullet, in greater range and in greater accuracy. Also, the Henry bullet is less affected by wind.

What breech-action should be fitted to this barrel to render it a perfect arm? This question has given rise to immense discussion and to innumerable experiments. Mr. Henry himself had a breech-action of great merit, which some persons thought it would be well to employ. But the question was directed to be settled experimentally, and the result of the experiments was that the Henry breech mechanism had to yield the palm to a mechanism designed by Mr. Martini, a naturalised Swiss subject. This action is best described by the drawings given in page 336.

The action consists, as will be observed, of a falling block, hinged upon a pin which passes through its rear end, the recoil being taken by the iron framework at the back. Inside this block is situated the striker, by means of which the cartridge is exploded, and the strong spiral spring by means of which the striker is actuated. The block is raised and lowered by a lever, which in the act of lowering the block also compresses the spring, thereby bringing the rifle to full cock; and the front end of the block striking smartly upon the bent lever, the extractor ejects the empty cartridge. When the fresh cartridge has been introduced, the block is returned to its place by the return movement of the lever, and the arm is ready for firing; or, if it be not desired to fire it immediately, there is a small safety-bolt, easily manipulated by the fore-finger and thumb, which serves to lock the arm and prevent it from going off. Also, the gun is provided with an "indicator" at the side, to show when it is cocked. The indicator, being attached to the "tumbler," moves with it and parallel to it; and as the arm cannot be cocked unless the tumbler be in a certain position, the indicator shows infallibly its condition.

The tests which the Martini-Henry breech-action has undergone have been extraordinarily severe, although scarcely more so than the criticism to which it has been subjected. This criticism has, however, had this good effect: if it has somewhat interfered with the early adoption of this arm, by rendering necessary continued trials, it has, through these trials, fully established the extraordinary merits of the breech-action. At first the objection was urged that, although one or two show specimens, prepared specially for trial, might succeed in satisfying such tests as the Committee were able to impose, the arms, if placed in the hands of the troops, would certainly break down. To meet this, 200 Martini-Henry rifles were issued to the troops, who for about a year and a half had them under

trial. The result of these trials, carried on in all climates, from India to Canada, in all weathers, and under all sorts of circumstances, has been to elicit most favourable reports of the arm. Then it was urged that at any rate the arrangements of the breech were mechanically defective; that no mechanical engineer could have any doubt on this point; that a mechanism radically unmechanical could not continue to give reliable and satisfactory results. Accordingly, the evidence was taken of three very eminent mechanical engineers—Professor Pole, Mr. Nasmyth, and Mr. Woods. These gentlemen, instead of pronouncing a condemnation of the mechanism, declared that it is an excellent piece of work, and passed high encomiums on its simplicity, strength, and efficiency. The criticism that as the recoil is taken by the breech axis pin, that pin must necessarily wear away or break in time, they met by the statement that the recoil is not taken by the pin at all, but by the socket behind the block, whence it is transmitted throughout the whole system of the rifle, the weight of which is thus brought to resist it; and this statement they supported by reference to a very simple experiment, in which the block axis pin had been replaced by one of lead, on which no mark of any recoil was perceptible. In another instance the gun was worked perfectly without any pin at all. The spiral spring has been a prominent point of attack. It has constituted, so to speak, the citadel of the system, and against it all the main efforts of the opponents of the arm have been directed. One inventor of a rival breech-action based his claim mainly on the substitution in his system of a flat for a spiral spring. This objection the mechanical engineers met very decidedly. For the purpose for which it is required in this gun—viz., to cause a striker to impinge directly upon the percussion-cap of a breech-loading cartridge—they greatly preferred the spiral to the flat spring. It is far cheaper—as a halfpenny to sixteen-pence—it admits of a far more compact arrangement of parts; it is, notwithstanding all that has been said to the contrary, quite as reliable as a flat spring—a point which they supported by quoting various well-known applications of spiral springs; it is quite as easy to make of uniform quality in large quantities; and as for the statement that the spiral spring gives more of a push than a blow, one witness showed mathematically that the blow which is struck by the spiral spring in the Martini-Henry is really a quicker, smarter blow than is struck by the hammer of the Snider. As to the merits generally of the spiral spring—the point which inventors of other systems have declared to be fatal to the Martini—all the mechanical witnesses agreed in pronouncing it thoroughly mechanical, sound, and reliable. Then it has been objected that the divided stock is weaker than the ordinary gun-stock. Not so, say the engineers; it is rather stronger; and if desired it can be made stronger still. Nor is this mere theory. They appealed to the results of an experiment which was carried out at Enfield in their presence to test this point. And so, before the independent testimony of thoroughly competent, indeed, distinguished witnesses, the criticisms which have been freely indulged in by those who have rifles of their own which they would prefer to see introduced, have melted away. Whether the criticism will therefore cease it is not easy to say; probably it will not. But the readers of these papers at any rate will have the assurance that the future arm of the British soldier, whatever may be said about it, has undergone tests and trials to which no other weapon was ever submitted; that it has passed one ordeal after another not merely satisfactorily, but triumphantly—the ordeal of the rigorous trials which were instituted by Lieut.-Colonel Fletcher's Committee, the ordeal of knocking about and handling by the troops, the ordeal of two public trials at Wimbledon, where the arm carried off the greater part of the more important breech-loading prizes; the ordeal of public criticism; finally, the ordeal of a minute scrutiny at the hands of professional mechanics. If an arm can stand all this, and come out unscathed, as the Martini-Henry has done, it is surely a fit arm to put into the hands of our troops. This, then, is the future weapon of the British soldier—the Martini breech allied to the Henry barrel.

The cartridge to be used with this arm is the Boxer, but of a form different from that in use with the Snider. The first cartridges made for the Martini were very long, the small diameter of the barrel and the large charge of powder rendering necessary this length so long as the cylindrical form of cartridge was retained. To this cartridge objections were made on account of its length. Accordingly the form was modified, the substantial features of the Boxer construction being retained. In the modified cartridge the body is enlarged in diameter, and tapered down at the fore-part to the diameter of the bullet. The outline of the cartridge is thus that of a long-necked bottle, whence the name by which it is frequently known, the "bottle-neck" cartridge. A drawing of this "short-chamber" cartridge, as it is officially designated, shows the details of the construction, and it will be observed, on a comparison of this drawing with that given in a former paper (page 272) of the Boxer cartridge for the Snider, that the construction of the two cartridges is practically the same. There is the thin coil-case, the iron disc base, the strengthening cup, the papier-maché wad by which the parts are held together, the cap and anvil arrangement for ignition.

But the fore-part of the cartridge is different; the mode of lubricating is different; the bullet (which is Mr. Henry's) is different; the cartridge is not covered with paper; and the base is strengthened by means of the insertion of a piece of tin between the folds of the brass, thereby obviating the necessity for additional strengthening cups. A few words may be said with regard to the bullet and lubrication. The bullet is solid, with the exception of a shallow cavity in the base, into which the folds of the paper which envelops the bullet are inserted. At its back end, the bullet is of the same diameter as the bore, viz., ·45 inches. It tapers slightly, until at the shoulder the diameter is only ·439 inches. In a former paper it has been explained that the main feature of the bullet for the original muzzle-loading Minié and Enfield rifles consisted in the arrangement by which the bullet was expanded into the rifling, by the explosion of the charge acting upon an iron cup, or a wooden plug in a hollow at the base. Thus the bullet entered the rifle fitting loosely, and left it fitting tightly. In a breech-loader, however, there is no necessity for having a bullet which will enter the barrel easily, as it is generally introduced into a chamber at the breech end, and may be made in the first instance of the full requisite diameter. We have seen, however, that Colonel Boxer in his bullet for the Snider did retain the plug expansion, with a view partly to getting the requisite length of bullet in a large-bore rifle without any undue increase of weight. But in the Henry rifle no such device is necessary, and Mr. Henry therefore made his bullet of the full diameter of ·45 inch, depending upon such slight enlargement as the bullet received by the opposition of its own inertia to the shock of discharge, to take up the rifling. The action of Mr. Henry's bullet therefore depends upon what is known as the "overtaking" principle, the back end of the bullet slightly overtaking the fore end, owing to the inertia of the mass in front, and thereby setting up, and expanding the bullet into the grooves.

The lubrication of this rifle is effected by means of a cylindrical wad of pure bees'-wax, placed behind the bullet, and enclosed in discs of jute cardboard, to prevent it from striking either to the bullet or to the powder. This wad was originally made solid, but it was found not to act perfectly in very cold weather, and it was therefore thickened and hollowed out in front, thus giving more space for the powder to act through, and less work for it to do. The wad is squeezed between the exploded powder charge and the bullet, and just as the bullet is set up and enlarged, so the wax wad is set up and enlarged, although of course to a far greater extent, and as it is driven through the bore, lubricating it effectually.

It remains now only for us to say a few words with regard to the powers of the Martini-Henry rifle, using the ammunition above described. The accuracy of shooting of the arm is remarkably great. The following facts extracted from official records are satisfactory upon this point. At 300 yards, the mean radial deviation of 20 shots fired from a fixed rest, has been as good as ·47 feet; at 500 yards, ·79 feet; at 800 yards, 1·29 feet; at 1,000 yards, 2·19 feet; at 1,200 yards, 2·28 feet. Perhaps these figures will scarcely convey to all our readers the impression which they would make upon the mind of any one who is familiar with the mode of estimating "figures of merit" in rifle-shooting, namely, to find out by calculation the centre of each group of 20 shots, and to find the mean distances of these shots from this centre. Obviously, the smaller this distance, the smaller the limits of the group, and the more ac-

curate the shooting. When a trial was recently made between the Snider, the Chassepot, and the Martini-Henry, the following results were obtained:—

	Martini-Henry.	Snider.	Chassepot.
500 yds.	·815 feet.	1·47 feet.	2·77 feet.
800 „	1·57 „	3·78 „	5·22 „
1,000 „	3·66 „	8·34 „	13·08 „

Putting this into a popular form of expression, it means that, if we take the Martini-Henry as a standard, as equal to 100, we have the following comparison—

	At 500 yds.	At 800 yds.	At 1,000 yds.
Snider =	55·4	41·5	43·9.
Chassepot =	29·4	30·0	28·0.

Or, expressing it more roughly still, we have the following tabular comparison of the performances of the rifles, namely:—

	At 500 yds.	At 800 yds.	At 1,000 yds.
Martini-Henry to Snider, as about	2 to 1	$2\frac{1}{2}$ to 1	$2\frac{1}{2}$ to 1.
Chassepot, „ „ „	3 to 1	3 to 1	3 to 1.

Let us now turn to the trajectory of the arm. It is obvious that the flatter an arm shoots—in other words, the lower its trajectory is — the more ground will the bullet cover in its flight. The greatest height of the trajectory of the Snider is 11·9 feet in 500 yards; of the Martini-Henry only 8·9 feet. The practical effect of this is that, supposing two men to be firing, lying on the ground, and aiming at the feet of a body of troops 500 yards distant, a body of infantry might safely cross the Snider range anywhere between 92 and 438 yards, the bullets flying over their heads, while in only from 139 to 396 yards would they be safe in the Martini-Henry range; and as for cavalry, while on the Snider range from 138 up to 400 yards they would be safe, there would on the Martini-Henry range be no spot which a cavalry soldier could pass in safety. Beyond 500 yards the advantage of the Martini-Henry rifle in respect of trajectory would be increasingly greater.

The next point is initial velocity—the velocity, that is to say, at which the bullet leaves the muzzle. This is as follows:—

Martini-Henry	1,365	feet per second.
Chassepot	1,391	„
Snider	1,262	„

It will be observed that the Chassepot bullet has a slightly higher initial velocity than the Martini-Henry, but the bullet being lighter (380 against 480 grains) it has less power to overcome the resistance of the air, and therefore soon loses this high velocity. At 150 yards from the muzzle, or even at a less distance, the Martini-Henry bullet will be travelling with a velocity equal to that of the Chassepot, and from that point forward the latter will gradually be losing in the race.

The effect of this high velocity, combined with a good weight and a small diameter, is to give the Martini-Henry bullet great penetrative power, as well as that low trajectory which has been spoken of. It has been found by experiment that the bullet will penetrate as follows:—$14\frac{1}{2}$ half-inch elm planks at 100 yards; 3 three-inch fir balks dry, in addition to 1 wet, at the same distance; 1 plate of ·261 inch iron at 200 yards; 4 thicknesses of 3-inch rope at 350 yards; a gabion filled with clay earth at 25 yards; a sap roller at 25 yards; a sand-bag at 100 yards.

While the normal accuracy of the Martini-Henry rifle is far greater than that of the Chassepot and Snider, and enormously superior to that of the needle-gun, which is by far the worst arm of the four, the Martini-Henry bullet is less affected by wind—a great advantage to the marksman. The cartridge is stronger and better than that of the Chassepot. The rapidity of fire is more than double: thus, at an official trial—

The Chassepot fired 20 rounds in 1 minute 42 seconds.
The Martini-Henry „ 0 „ 48 „

Thus in seven points—namely, (1) increased strength and safety of ammunition, (2) greater accuracy, (3) longer range, (4) flatter trajectory, (5) higher penetrative power, (6) greater safety, strength and simplicity of construction, (7) increased rapidity of fire—the Martini-Henry is much superior to the Chassepot.

It is also, although in a less degree, superior to the Snider on most of these points. Such is the weapon with which the British soldier will in future be armed.

This brings to a close our remarks on Small Arms. In our next article we shall pass to the subject of Great Guns, which we propose to treat in an equally exhaustive manner.

Fig. 7.

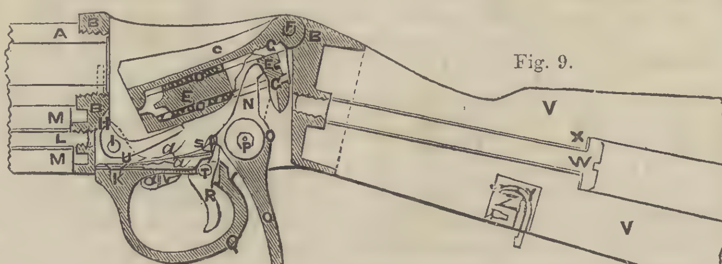


Fig. 9.

Fig. 8.

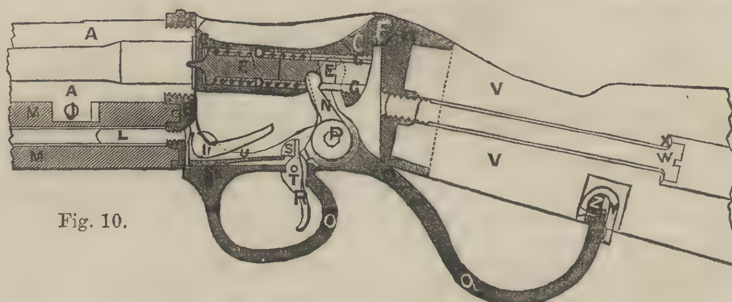


Fig. 10.

Fig. 7. BOXER-HENRY CARTRIDGE, ELEVATION. Fig. 8. BOXER-HENRY CARTRIDGE, SECTION. Fig. 9. SECTION OF BREECH OF MARTINI-HENRY RIFLE, OPEN. Fig. 10. SECTION OF BREECH OF MARTINI-HENRY RIFLE, CLOSED.

Refs. to Letters in Figs.—Fig. 9, 10:—A, barrel; B, body of breech-action; C, block; D, main-spring; E, striker; F, block axis pin; G, stop nut; H, extractor; I, extractor axis pin; J, pin for barrel stud-hole; K, trigger and rest spring screw; L, cleaning rod; M, fore-part of stock; N, tumbler; O, lever; P, lever and tumbler axis pin; Q, trigger-plate and guard; R, trigger; S, tumbler rest; T, trigger axis pin; U, trigger and rest spring; V, hind part of stock; W, stock-bolt; X, stock-bolt washer; Y, lever catch-spring; Z, lever catch-block and pin; *a*, locking bolt; *b*, locking bolt thumb-piece; *c*, thumb-piece screw; *d*, locking bolt-spring.

4

VEGETABLE COMMERCIAL PRODUCTS.—XI.

TEXTILE PLANTS, OR PLANTS FROM WHICH WE DERIVE CLOTHING AND CORDAGE (*continued*).

THE value of cotton in commerce depends on the length and strength of the silk or staple. Cottons may be divided into the long silk and short silk. The United States generally furnish the short silks in the greatest quantity, with the exception of one sort, known as the Georgia long silk, or Sea-island cotton, of which the production elsewhere is very limited. Cotton threads are numbered from 1 to 300, according to the degree of fineness to which they are spun. In weaving, the cross threads or woof are shot by the machine across or at right angles to threads extending longitudinally, called the warp. Long silk cotton is generally spun into the threads for the warp, and the short silk is used for the woof.

The chief seats of the cotton manufacture in the United Kingdom are Manchester, Bury, Oldham, and Glasgow. Most of the many thousands of cotton-mills give employment to from 50 to even 1,500 hands, presenting the most perfect order in every department. All these persons are employed by means of the fine white silky hairs with which the Creator has clothed the seed of the cotton plant, in order to effect its dispersion, and which the ingenuity and skill of man now manufactures into clothing for many millions of the human race.

JUTE, or GUNNY FIBRE, is the produce of *Corchorus capsularis*, L. (natural order, *Tiliaceæ*), an annual, growing from twelve to fourteen feet high.

The fibre which is contained in the bark is generally about eight feet in length, and is obtained by treatment very similar to that adopted with the flax and hemp plants. Jute fibre is fine, and has a remarkable satiny lustre, so that it is sometimes mixed with the silk in the fabrication of cheap satins, and is very difficult to detect in the goods. Its chief use, however, is for making coarse canvas, or *gunny*, as it is called in India. Rice, oil-seeds, dye-stuffs, cotton, and sugar, are all sent to us from India in gunny bags or bales. When wet, jute fibre quickly rots, so that it is not adapted for the manufacture of either sail-cloth or cordage; but notwithstanding this, it is often mixed with hemp for the latter. The quantity imported in 1868 was 2,182,521 cwt.

LEAF OF THE CASTOR-OIL TREE.

NEW ZEALAND FLAX (*Phormium tenax*, Forst.; natural order, *Liliaceæ*).—A coarse growing plant, with long narrow leaves, the slender fibres of which glisten like silk, and are white as snow. Its flowers are of a brownish-red colour, and not at all ornamental.

This plant inhabits the marshes of New Zealand, but grows well in any soil; and in mild climates, such as the south of France, winters in the open air. It affords a fibre of great strength, stronger than hemp, which is extracted by maceration, drying, and heckling, as in the case of the other products. Good ropes can be made from the coarser, and very fine linen from the finer fibres. The quantities imported are at present inconsiderable, owing to the circumstance that the strength of the fibre is injured by maceration. No machinery has yet been contrived which can approach or even imitate the dexterity of the native women in separating the fibre from the coarser parts. New Zealand flax fibre will not bear a cross strain, and therefore cannot be tied into a knot without breaking.

COIR-FIBRE (*Cocos nucifera*, L.; natural order, *Palmaceæ*).—This fibre is obtained from the outer husk of the cocoa-nut. It is stronger than hemp, and more capable of withstanding the action of water. It is separated from the husk by beating, and then cleaned by heckling in the usual manner. The coir-fibre thus procured is spun by the natives of India and Ceylon into yarns of different length and thickness, which are largely exported to Europe. The yarn on reaching this country is manufactured into ropes, door-mats, and floor-mattings, which are far more durable than those made from bristles. In India, coir-fibre is very generally used for ship-cordage and fishing-nets. In 1850 about 10,661 tons were imported into London and Liverpool, chiefly from Ceylon and Bombay.

CARLUDOVICA PALMATA, L. and P. (natural order, *Pandaneæ*).—This species of screw pine is terrestrial, and bears fan-shaped glabrous leaves from six to fourteen feet long, and four feet in breadth. It ranges from 10° N. to 2° S. latitude on the American continent.

Panamá hats, which are distinguished from all others by consisting of a single piece, as well as by their durability and flexibility, are so named because they are shipped through Panamá, though a large proportion are manufactured in Guayaquil, Ecuador. The finest hats are made in South America with fibre of the unexpanded leaf, called "torquilla," from which are also made very fine hammocks.

The leaves are gathered before they unfold, all the ribs and coarser veins are removed, and the rest, without being separated from the base of the leaf, is reduced to shreds. After having been exposed to the sun for a day, and tied into a knot, the straw is immersed into boiling water until it becomes white; it is then hung up in a shady place, and subsequently bleached for two or three days. The straw (*paja*) is now ready for use, and in this state is sent to different places, where the Indians manufacture from it hats, hammocks, and those beautiful cigar-cases which cost as much as five and six pounds a-piece. The plaiting of the hat is done on a block, which is placed upon the knees; it is commenced at the crown and finished at the brim. According to the quality of the hats, more or less time is occupied in their completion: the coarser ones may be finished in two or three days, while the finest take as many months.

The average export from Guayaquil has been in the past six years from 15,000 to 16,000 dozens annually, the price varying from 2 to 130 dollars, according to fineness. Lately the leaves or raw material have been in demand for export, the average quantity shipped being about 200 to 250 cwt. annually.

These hats are also made in Veraguas, Western Panamá, Costa Rica, and New Granada. The petioles of the leaf are made into baskets, called *petacas*, the fibre being variously dyed.

MANILLA HEMP (*Musa textilis*, Tournef.; natural order, *Musaceæ*) produces a woody fibre, which is used in India in the manufacture of fine muslins; the most exquisite textile fabrics and the elegant Manilla hats are manufactured from it.

II.—OLEAGINOUS PLANTS, OR PLANTS YIELDING VALUABLE OILS.

Oil is of the greatest importance in the arts. It is extensively used for burning in lamps, for diminishing friction in machinery, for making candles and soaps, in the manufacture of paints and varnishes, and in wool-dressing—five gallons of olive, rapeseed, or other oils being used in the preparation of every pack of wool—also as an article of food, and as medicine. Oils are distinguished into two kinds: fixed or fat oils—which are obtained by pressure from the fruits or seeds of plants—and essential oils. The fixed oils burn with a clear white light, and boil at a high temperature, about 600° F.; most are liquid at the ordinary temperature, but cocoa-nut and palm oils are solid at 50° or 60° F. All the fixed oils are nearly inodorous, and lighter than water. The volatile or essential oils give off vapour at the temperature of boiling water when mixed with water, or under 320° F. by themselves.

The following are a few of the most important plants which yield the oils of commerce:—

(a) FIXED OILS.

PALM OIL is principally produced from the fruit of *Elais Guineensis*, L., a native of the western coast of Africa. The fruit is about the size of an olive, of a yellow colour, three-fourths of which consist of a yellow oily pulp. This fruit is crushed and the oil extracted from the albumen by boiling in water. Palm oil is used in England principally in the manufacture of yellow soap, but with the Africans it is an article of food. A generation ago large tracts of country on the western coast of Africa were covered by the oil palm, then little cared for; now a large foreign demand for palm oil has sprung up, and with it property in these trees; and this oil trade has stopped the slave trade on the Gold coast, where it once flourished, and at the mouth of the Niger. The average imports of palm oil into Liverpool alone have been for several years past upwards of 18,000 tons, giving employment to 30,000 people. In 1868 the palm oil imported into the United Kingdom amounted to 960,059 cwt. Industry and a desire of accumulating property are at last manifest amongst the African population, and everywhere are now to be seen on this coast the germs of a nascent civilisation.

COCOA-NUT OIL is obtained from the albumen of the kernels of the cocoa-nut (*Cocos nucifera*, L.); it is principally used for making cocoa-stearine for candles. In Trinidad and Demerara it is used by the coolie labourers as we employ butter. The imports in 1868 were 194,752 tons, almost the whole of which came from Manilla and Ceylon.

CASTOR-OIL PLANT (*Ricinus communis*, L.; natural order, *Euphorbiaceæ*).—This plant, in temperate climates, is a large herbaceous annual, with palmate peltate leaves, and monœcious flowers in terminal panicles, the lower male, the upper female. The capsules are prickly, globose, three-celled, with one seed in each cell. The seeds are ovate, shining, of a grey colour, marbled with black. The form of the leaf is shown in the preceding page.

The castor-oil plant is a native of India, Africa, and the West Indies. In warm climates it acquires a woody stem, and becomes a tree, rising in India often to a height of thirty feet. Nevertheless, it is still the same plant, and not entitled to be considered as a distinct species, although a woody perennial; the leaves and flowers are unaltered, and the seed, if sown in temperate climates, produces herbaceous plants in every respect the same as those in common cultivation.

Castor oil is obtained by expression from the seeds, without heat, hence it is called "cold-drawn castor oil." The seeds, sewn up in horsehair bags, are crushed by the action of heavy iron beaters, and the oil, as it oozes out, is caught in troughs and conveyed to receivers, whence it is bottled for use. Castor oil is brought over from the East Indies in small tin cases, closely soldered, and packed in boxes, weighing about 2 cwt. each. In 1853, 23,597 cwt. were imported into the United Kingdom. Castor oil is much used in medicine, as a mild and certain purgative.

OLIVE OIL (*Olea Europæa*, L.; natural order, *Oleaceæ*).—The olive-tree is a small evergreen, much branched, and covered with a greyish bark. The olive itself is a drupe or stone fruit, with a fleshy covering, about the size, shape, and colour of a damson. When ripe this fleshy covering contains an abundance of olive oil, which it yields by expression.

The olive is indigenous to Palestine, Greece, and the slopes of the Atlas Mountains in Africa. It is now widely diffused in Europe, and is cultivated with great success in Italy, Spain, the south of France, Naples, Sicily, Southern Illyria, Lombardy, and Dalmatia.

The olives are gathered when nearly ripe, and the oil is drawn from them by presses and mills, care being taken to set the mill-stones so wide apart that they will not crush the nut of the fruit. The pulp is then subjected to a gentle pressure, in bags made of rushes, and the best or *virgin* oil flows first. A second oil, of inferior quality, but fit for table use, is obtained by moistening with water the residuum, breaking the nuts, and increasing the pressure; lastly, more water is added, and the residuum is again re-pressed, the product being an impure oil, fit only for soap-making or for burning. Spanish or Castile soap is made by mixing olive oil and soda; and soft soap, by mixing fat, or fixed oil, with potash. The *marc* of olives, as the residuum is called after the oil has been expressed, is valuable either as manure or as food for cattle.

The virgin oil is called Florence oil, and is imported in flasks surrounded by a network formed of the leaves of a monocotyledonous plant. It is used at the table under the name of salad oil. Gallipoli oil forms the largest portion of the olive oil brought to England; it is imported in casks. Olive oil is largely used in this country in dressing woollen goods, and for machinery. In 1868, 17,585 tuns of this oil were imported into the United Kingdom.

RAPESEED, the seed of *Brassica napus*, L.; natural order, *Cruciferæ*.—This plant grows wild in many parts of England, and is cultivated extensively in this country, in France, and in Germany, for the sake of the oil procured from its seeds. Rape oil is more suitable than any other oil for the lubrication of machinery, and is now much used for locomotives, marine engines, and for burning in lamps. A single locomotive consumes from 90 to 100 gallons of oil annually. The consumption of oil by the London and North-Western Railway Company alone is every year 40,000 gallons. Good English rapeseed yields an oil very superior to that obtained from foreign rape; nevertheless, in 1868, we imported 356,884 quarters of rapeseed, and about 300 tuns of the oil in 1851, chiefly from France and Germany.

LINSEED, the seed of *Linum usitatissimum*, L.; natural order, *Linaceæ*.—We have already described this plant, under the name of flax. Flax seed or linseed yields a most valuable oil, known as linseed oil, largely employed in the arts, especially in painting and in the manufacture of printers' ink. It becomes solid on exposure to the action of the air, or, in other words, is one of the drying oils. This article is always imported in the form of seed. In 1868 the imports into Great Britain were 635,528 quarters, principally from the East Indies and Russia. Smaller quantities come from Prussia, Germany, Egypt, and America.

SESAME (*Sesamum orientale*, L.; natural order, *Pedaliaceæ*).—This is a small showy annual, indigenous to India, and to the whole of Southern Asia, from Japan and China to the shores of the Mediterranean. In these countries it is much cultivated, and the oil, yielded in abundance by the seed, is used for dressing food, and as a common lamp-oil. In the East, this oil has some considerable repute as a softener and beautifier of the skin, and as an application to furfuraceous eruptions.

Sesame oil is without odour, and does not easily become rancid. It is frequently used for the adulteration of balsams and volatile oils. Large quantities of the seed are brought to this country from the East Indies and Egypt.

We have now noticed the principal vegetable fixed oils. There are several other oil-producing plants in the market, but not much in demand at present. The following are deserving of notice:—Croton Oil (*Croton tiglium*, Lam.). This oil is a valuable and most powerful purgative, capable in over-doses of destroying life, and only administered one drop at a time, in cases where it is of the utmost importance to make a speedy impression on the bowels, and where the patient has difficulty in swallowing. It is also valuable as a counter-irritant. Croton oil is obtained by expression from the seeds. The common hazel-nut (*Corylus Avellana*, L.) yields an oil most valuable for the delicate machinery of watches, diminishing the friction of the pinions, the axles of the wheels, and other rapidly moving parts, which would otherwise wear injuriously, and speedily become disordered. The oil of almonds also is employed for the same purpose. Other oils are obtained from cotton seed, ground nut, carthamus seed, etc.

SEATS OF INDUSTRY.—VI.

By W. WEBSTER.

LOWELL AND ROUEN.

LOWELL.

LOWELL is the principal centre of cotton manufacture in the United States, and hence is frequently described as "the Manchester of America." The story of its foundation and progress forms one of the most interesting and encouraging chapters in the history of modern industry. It owes its name, its origin, and its prosperity exclusively to industrial enterprise, and is remarkable even among the towns of the New World for the rapidity of its growth.

The site occupied by the busy and thriving town of Lowell possesses few natural advantages, and even the water power on which its prosperity depends had, to a great extent, to be

created. In 1792 a company, incorporated under the name of the Locks and Canals Company, obtained powers to construct a canal for the purpose of navigation round the Pawtucket falls in the Merrimack river, and it was many years after the completion of this work before it was seen that this canal could be utilised for manufacturing purposes. It was in 1821 that the project of establishing a cotton manufactory at Lowell took a practical shape. In that year several gentlemen purchased about 400 acres of ground, now forming the heart of Lowell, and built a factory and dwelling-houses for the operatives. This body of industrial pioneers was subsequently incorporated as the Merrimack Company, which is still in existence, and is the largest of the manufacturing establishments in Lowell. Since it was originally constructed, the canal has been greatly extended, and in 1847 it was entirely rebuilt. The main canal is one mile and a half in length, sixty feet wide, and of a depth admitting the passage of vessels drawing eight feet of water. It is fed from a dam erected at the head of the Pawtucket falls, and its waters are distributed by means of numerous channels branching off in various directions, and discharging into the Merrimack and Concord rivers. This canal is said to be capable of supplying 1,250 cubic feet of water per second, or fifty mills with twenty-five cubic feet per second for each.

In 1826 Lowell was incorporated, the name bestowed upon it being a recognition of the services rendered to the American community by Francis C. Lowell, a Boston manufacturer who had been largely instrumental in introducing cotton manufacture into the United States. The history of the town from this date is composed, for the most part, of the rise and progress of a dozen companies or "corporations" for the manufacture of cotton cloth. According to the published statistics for the year 1870, these companies own fifty mills containing 12,940 looms and 526,710 spindles, and give employment to 14,898 persons, consisting of 6,035 males and 8,863 females. The aggregate capital stock invested in the manufacturing companies of Lowell is returned at 13,650,000 dols., and the weekly product at 2,240,000 yards of cotton goods, 21,667 yards of woollen goods, 35,000 yards of carpeting, 2,500 shawls, and 10,900 dozens of hosiery. The raw material consumed during the same year amounted to 612,000 pounds of cotton, and 97,000 pounds of clean wool per week. From a table in the New American Encyclopædia, we gather that there were twelve manufacturing companies in Lowell in 1860, with an aggregate invested capital estimated at 13,000,000 dols., employing 12,507 operatives, working up 805,770 pounds of cotton, and 91,000 pounds of clean wool per week; and producing 2,463,000 yards of cotton goods, 44,000 yards of woollen goods, 25,000 yards of carpeting, and about 50 rugs per week. A comparison of these figures shows that there has been but little increase in the trade during the intervening decade. There has, however, been a slight augmentation of the population, which in 1860 numbered 36,827, and in 1870 had risen to 40,937. The taxable property of Lowell for the latter year was valued at 25,000,000 dols. Eight of the manufacturing companies in Lowell, including the Merrimack, are devoted entirely to the manufacture of cotton goods. One of the others produces carpets, rugs, and pantaloon stuffs, in addition to cotton-cloths; and another manufactures broad-cloths, doe-skins, cassimeres, and shawls. The Lowell Machine Shop, which was incorporated in 1845, has a capital of 600,000 dols., and employs 550 operatives in the manufacture of cotton machinery, locomotives, etc.; consuming 3,000 tons of wrought and cast iron per annum. The Lowell Bleaching Company, which dates from 1832, has a capital of 300,000 dols., and employs about 270 persons in dyeing some 15,000,000 yards, and bleaching other 8,000,000 yards of cloth per annum.

The mode of life of the operatives in Lowell is peculiar. When this spot was selected as the site of a cotton manufactory there were no dwelling-houses in the vicinity to accommodate the workmen, and the proprietors of the mills had accordingly to supply the want. The system then inaugurated is still maintained. Each of the manufacturing companies owns from twenty to thirty dwelling-houses, which are leased at a nominal rent to responsible persons as boarding-houses for the workpeople employed at the several mills. Some of these boarding-houses are barracks, capable of accommodating from forty to fifty inmates. The sexes are lodged in separate dwellings, and only persons employed by the company to which the house belongs are eligible as boarders. The companies also support an hospital, for the benefit of their operatives. All workpeople who are able to pay for the use of the hospital, however, are required to do so, and the employers of those who cannot afford to pay are charged with the cost of their treatment.

Besides the large manufacturing companies, there are in Lowell several enterprising private firms engaged in various manufactures. A few years ago it was estimated that the aggregate capital invested in mills and machinery by individual proprietors amounted to 400,000 dols., and that they gave employment to upwards of 1,500 persons.

There are in Lowell six banks of issue and three savings-banks. The amount of the deposits in the latter was recently returned at 2,605,148 dols., and the number of depositors at 12,192. After deducting the cost of board, the average weekly wages of the female workers is said to be 2 dols., and that of the males 4 dols. 80 cents. There are two loan and fund associations, and three insurance companies in Lowell. The provision made for the religious and secular education of the inhabitants of this manufacturing town probably furnishes even a more remarkable proof of their general prosperity than the statistics of the savings-banks. There are no fewer than twenty churches in Lowell, or one for every 2,000 of the population. Seven of these are Congregational, three Baptist, three Methodist, three Roman Catholic, two Universalist, one Episcopalian, and one Freewill Baptist. Besides one high school, eight grammar schools, and three intermediate schools, Lowell possesses fifty-one schools for primary instruction, the aggregate of scholars at the latter being 9,599, and the average daily attendance 5,450. There are several libraries in the town, the principal being the Mechanics' Association Library, which contains upwards of 6,000 volumes. During the past forty years, newspapers have been started in Lowell at the rate of about one per annum, and four of them are still continued.

Lowell is the third shire town of Middlesex, Massachusetts, and is situated on the Merrimack, near the mouth of the Concord, about five-and-twenty miles distant from Boston in a north-westerly direction. It is connected with Boston by the Boston and Lowell Railroad, and with various points to the north by means of several lines of railway. The local government consists of a mayor, eight aldermen, and twenty-four councillors.

ROUEN.

The ancient city of Rouen, the *Rothomagus* of the Romans, one of the chief seats of manufacture and trade in France, presents a striking contrast to the modern town of Lowell. If the history of the latter is unusually monotonous and uneventful, even as compared with other towns in the New World, that of the former is certainly more rich in stirring associations than the generality of the manufacturing towns of Europe. The occupation of Rouen by a body of German troops, towards the end of 1870, is assuredly the most important occurrence that has taken place there within the memory of the oldest inhabitant, but it can hardly be classed among the great events in the history of the city. Since it was seized by Rollo and his followers in 842 and made the capital of the Norsemen in France, in conformity with a treaty wrenched from Charles the Bold, Rouen has changed hands several times. It was the residence of the Dukes of Normandy till the year 1066, when Duke William made his successful invasion of England, and brought his court over to London; and it continued to be the capital of Normandy and the seat of the government of that province while it was in the possession of the Conqueror's successors, up to the time of Richard Cœur de Lion. In 1204 Rouen was besieged by King Philip Augustus, and annexed to France along with the greater part of the duchy of Normandy. This monarch left his mark on Rouen, for it was he who built the celebrated cathedral of St. Ouen, one of the grandest specimens of Gothic architecture in Europe, and by far the most interesting of the many fine Gothic churches the city can boast. Among the numerous relics preserved in the five-and-twenty richly-carved chapels of this cathedral, is the heart of Richard Cœur de Lion. But Rouen again passed into the possession of the English in the first half of the fifteenth century; and it was during their occupancy that the heroic Jeanne Darc (commonly but improperly written d'Arc) was burned alive as a witch in the public square where her statue

now stands, and which has since been called in memory of her, Place de la Pucelle. After being thirty years under the power of the English, Rouen was re-captured by the French in 1449.

Next to Lyons, Rouen is the most important manufacturing town in France. The principal branches of industry cultivated in the city are cotton manufactures, including checked and striped cottons, commonly known as *Rouenneries*, nankeens, dimity, lace, cotton velvets, shawls, etc. It also contains extensive manufactories for the production of hosiery, mixed silk and wool fabrics, blankets, flannels, hats, cordage, cotton and linen yarns, shot, steel, lead, chemicals, paper, etc. It is also noted for its sugar refineries and potteries; and ship-building and machine-making are prosecuted with great success. The trade of Rouen has reached considerable proportions. In years when France is favoured with a superabundant harvest, large quantities of flour of a high quality are exported; and there is a constant trade in wine, sugar, and other French products, as well as in goods manufactured in the city.

Rouen is the capital of the department of the Lower Seine, and is situated on the river Seine at a point eighty-seven miles west from Paris, and seventy miles from the sea, including the windings of the river. Vessels of 200 tons burden can be loaded at the handsome quays which have been constructed on the banks of the river. The streets of the city are narrow, and the houses for the most part are built of wood. Among the most important public buildings may be mentioned the Palace of Justice, the theatre, and the Hôtel de Ville. The latter includes a public library, containing 40,000 volumes, and a splendid collection of paintings. There are several literary and scientific institutions and societies, and a large number of good schools established in the city. Rouen is the seat of various judicial and administrative authorities, and especially of a Tribunal of Commerce. In 1862 the population numbered 94,679, and is believed to amount at present to about 100,000.

APPLIED MECHANICS.—VIII.

BY ROBERT STAWELL BALL, A.M., LL.D.,

Astronomer-Royal for Ireland.

THE MECHANICAL PRINCIPLES OF BRIDGES: THE GIRDER—THE WOODEN BRIDGE—THE ARCH.

BRIDGES are of very varied form and construction. A tree which has fallen across a stream is, perhaps, the simplest bridge, and from this natural bridge up to such superb structures as span the Menai Straits, every conceivable intermediate link is to be found. In the present lesson we shall first consider the most simple type of bridge—that of a single beam or girder—and afterwards examine some more complicated constructions of this class.

THE GIRDER.

What is known in Mechanics as a girder will be understood from the accompanying figure. Let P Q (Fig. 1) be a beam, whether of wood, or cast-iron, or wrought-iron. This beam is supported at its extremities by A and B, and from its centre a weight is suspended. Now this weight, if not too large for the strength of the beam, is supported, and the beam is said to be strained transversely. Instead of having one weight attached to the beam, several weights might be suspended from it in different places, as in Fig. 2; or, finally, as in Fig. 3, the beam may be secured by having one end, P, firmly embedded in masonry or some secure support, and have a weight, W, suspended from the other end, Q.

In all these cases, when a beam is strained by a force or forces tending to break it across transversely, the beam is called a *girder*.

We shall first examine the simple case of a beam supported at each end, and bearing a weight in the middle (Fig. 1). When a weight is attached, the beam is seen to bend down a little in the centre; as the weight is increased the curvature increases, until, when the weight reaches a certain amount, the beam breaks.

It will be important for us to determine how the magnitude of the load which will break the beam is connected with its dimensions of length, breadth, and depth. It is manifest that the longer a beam be, the weaker it is, provided its section remain the same. It is easy to prove, in fact, both from theory and from experiment, that the breaking-load of a beam varies inversely as its length. Thus, for example, a beam of wood six inches square and twenty feet long is only half as strong as a beam six inches square and ten feet long. The effect of the section of a beam upon its strength is also to be ascertained without much difficulty. It is well known that a beam whose section is not square is stronger when placed edgewise than when placed flatwise. By actual trial, it will be found that if two perfectly similar and equal beams be taken, and that one beam be broken edgewise and the other be broken flatwise, the load necessary in the former case is to the load necessary in the

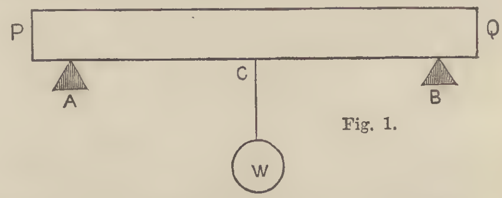


Fig. 1.

latter case in the proportion of the depth of the beam to its breadth. From this law, and that which refers to the length, we shall be able to deduce an expression for the breaking-load of any beam of any material, provided that its section be rectangular and constant.

It is a well-known rule among practical men that a beam of cast-iron, one foot long and one square inch in section, is broken by a load of one ton: let us deduce from this result the expression for the breaking-load of any beam of cast-iron which is l inches long, b inches broad, and d inches deep.

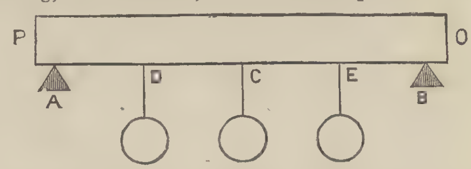


Fig. 2.

A beam whose section was one square inch and whose length was l inches would require a load determined by the following proportion:—

$$l : 12 :: 1 \text{ ton} : \text{answer}.$$

This proportion follows at once, from the law that the breaking-weight is inversely as the length: we infer, then, that for a bar l inches long and one inch square the breaking-strain is

$$\frac{12}{l} \text{ tons.}$$

The beam that we have supposed is b inches broad; it is therefore the same as b beams, each one inch broad, and d inches

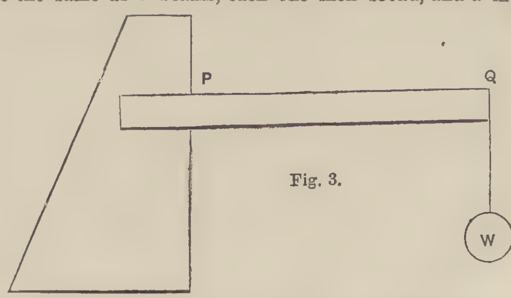


Fig. 3.

deep, standing side by side. Hence, the strength of the beam is b times the strength of a beam l inches long, d inches deep, and one inch broad, standing edgewise.

By the second law, a beam one inch broad and d inches deep is d times as strong as a beam d inches broad and one inch deep; and hence the original beam is $b \times d$ times as strong as a beam d inches broad and one inch deep. But a beam d inches broad and one inch deep is d times as strong as a beam of the same length which is one inch square. This is evident, for we may manifestly conceive that d beams, one inch square, placed side by side are identical in strength with the solid beam which

would be formed by making them cohere together. This would not, however, be true of beams placed one over the other. We infer, therefore, finally, that the beam l inches long, b inches broad, and d inches deep is $bd \times d = bd^2$ times as strong as a beam of the same length and one inch square; but we have already seen the strength of the latter to be

$$\frac{12}{l} \text{ tons,}$$

and therefore the breaking strength of the entire beam is—

$$\frac{12bd^2}{l} \text{ tons.}$$

This may be expressed in the following manner:—

$$12 \frac{\text{area of section} \times \text{depth}}{\text{length.}}$$

All the magnitudes are to be expressed in inches, and the answer will be in tons.

Example.—To find the breaking-strain of a cast-iron beam twenty feet long, six inches deep, and two inches broad.

The area of section is

$$6 \times 2 = 12 \text{ inches,}$$

and therefore the answer is

$$12 \frac{12 \times 6}{240} = 3{\cdot}6 \text{ tons.}$$

The expression we have here deduced for cast-iron holds also for other substances, the only difference being that the numerical co-efficient, which is 12 for cast iron, must be replaced by one appropriate to the particular material of which the beam is composed.

Thus, in the case of a beam of pine, the breaking-load, expressed in pounds, is given by the expression—

$$6{,}000 \frac{\text{area of section} \times \text{depth}}{\text{length}}.$$

For example, a piece of pine, ten feet long and six inches square, has a breaking strain of

$$6{,}000 \frac{36 \times 6}{120} = 10{,}800 \text{ pounds.}$$

In general, the strength of any beam is represented by

$$S \frac{\text{area of section} \times \text{depth}}{\text{length}}.$$

The values of S for certain substances are given in tables which will be found in treatises on Applied Mechanics.

We have hitherto only discussed the case of Fig. 1, in which the load is applied at the centre of the beam. We have now to consider the case of Fig. 2, where the load, instead of being applied at one point, is distributed over several. A beam in this condition is always able to bear more than when the load is applied entirely at the centre. The most important case which occurs in practice is where the load is distributed uniformly along the beam; as, for example, when a beam, supported at each end, has to sustain the weight of a wall of masonry. In such a case as this every inch of the length of the beam has the same pressure to support. To break a beam by a load applied in this manner requires twice as much weight as when applied at the centre only, and therefore the preceding expression will be applicable if the values of S be doubled.

In large beams the weight of the beam itself forms often a large portion of the load which it has to support, and this pressure is, of course, distributed along the length of the beam. In fact, the dimensions of the largest beams are limited by the consideration that, beyond a certain span, it is impossible to construct a beam which should sustain its own weight.

In Figs. 1 and 2 we have supposed that the ends of the beam are free, and when the beam is loaded the ends curl up slightly. If, however, the ends of the beams be firmly secured by being embedded in masonry, as the end P of the beam in Fig. 3, the strength of the beam is greatly increased, and it will be found that nearly double the load is now necessary to break it than was before required.

The beam of Fig. 3, in which the weight is suspended at one end while the other is fixed, is only one-fourth the strength of a similar beam supported at each end and laden in the centre, in the manner represented in Fig. 1.

THE WOODEN BRIDGE.

We shall now examine a few of the simple mechanical principles that are employed in the construction of a timber or iron bridge. The subject is here divested of the complexity which belongs to it in practice, and for information on which reference must be made to actual engineering works. This lesson is rather to be regarded as an illustration of mechanical principles than as a treatise on the building of bridges, which would, of course, be wholly out of place here, and is a difficult subject.

It will be found both easy and instructive to verify experimentally the principles that are here laid down; the apparatus necessary for this is simple and inexpensive. A number of slips of pine half an inch square, and of various lengths, from one foot to four feet, form the only materials necessary for the bridges which will be described in this lesson. These miniature wooden beams are to be fastened together in any positions that may be desired by means of cramps, such as that shown in Fig. 4, and which can be procured in any tool-shop; they should open to about two inches, as sometimes three beams must be fastened by the same cramp. The use of these cramps dispenses with the necessity of any other fastenings, for it will be found that the slips thus fastened together will bear a very great strain, amounting to 100 pounds or more, without slipping. Thus, with the greatest facility, bridges and other structures may be built up, and actually loaded with considerable weights, 14 pounds, 28 pounds, 56 pounds, etc., to test their strength. Possessing a few dozen of these slips of wood, and a corresponding number of cramps, many varieties of simple bridges may be tested, the same slips re-appearing in different combinations; and the apparatus may also be used for constructing models of roofs, and many other pieces of framework which will suggest themselves to the inquiring student. It will probably be found surprising what efficient joints are produced by the compression of the wood in the cramp; but, in cases of very great strains, the danger of slipping will be lessened by interposing two small pieces of sand-paper, back to back, between the surfaces of wood in contact. A few larger cramps will often be found useful for securing the important joints more firmly than is possible with the small cramps; the bruising of the slips may be diminished if necessary by the interposition of small slips of card-board between the iron and the wood.

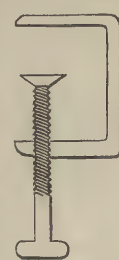


Fig. 4.

Let us suppose that it is desired to make a foot-bridge from one support, A, to another, B (Fig. 5). The most simple way of doing it, if the distance be not great, is to lay a plank of sufficient strength across, with its ends on each support; and for a short distance no method can be more efficient. To consider the strength of such a bridge, we must remember what has been already proved, that the load being the same, the weakness of the bridge increases proportionally to its length, and hence we see that the longer is the distance from A to B, the stronger must the planks be; but with an increase in the strength—that is, in the dimensions of the plank—there is a corresponding increase of its weight, and therefore an addition to the load which it has to sustain. When to this we add that there is, of course, a practical limitation to the magnitude of planks, we see at once that when the distance between A and B exceeds a certain amount, a bridge consisting of a single unsupported plank is a practical impossibility. It will be found that a slip of pine half an inch square, and resting on two supports, the distance between which is ten inches, would be broken by suspending a weight of about 80 pounds, more or less, according to the quality of the wood, at its middle point; hence we should infer, and we can easily verify by experiment, that a rod of the same wood resting on two supports forty inches distant, would be broken by a weight of about 20 pounds. We shall then examine the means by which a bridge consisting of a single plank can be strengthened. For convenience, we shall confine our attention to the rod of pine half an inch square and four feet long, being one of those with which the experiments are made, and, of course, the observations will apply, *mutatis mutandis*, to every other case

Let A B be a single beam, which is too long when unsupported

to form a safe bridge for the load which it has to carry. If, by means of a pedestal, it could be directly supported at the middle, at the point X, its strength would be doubled, because then it would be equivalent to one beam, A X, resting on the supports A and X, and to another, B X, resting on B and X; and since the strength of a beam varies inversely as its length, each of these portions is twice as strong as the whole beam was before, and therefore the bridge will now support double the weight which it could carry originally.

If three pedestals are applied, the length A B is divided into four parts; each part is, therefore, four times as strong as the unsupported plank A B, and therefore the supported bridge is four times as strong as it was before the pedestals were applied to it.

Whenever it is possible to have a number of pedestals under a bridge, they form the most suitable and efficient means of support, but in the majority of cases it will not be possible, and other means of support must be sought.

If a rod of pine four feet long be supported at the ends A and B, it would sustain about 20 pounds hung at its middle. Let the points of trisection, P and Q, of this beam be taken. If these points could be firmly supported, we should then expect, according to the principles already explained, that the strength of the rod would be increased threefold. Now, if with the help of cramps another rod be fastened to A B at P, and to the support at C, and a second rod, Q D, be similarly attached, the desired object is accomplished.

It will be found on trial that the sustaining power of the

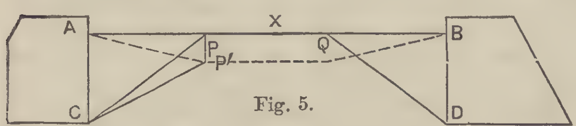


Fig. 5.

bridge has been vastly increased, and it will also be noticed that, whereas before it yielded and bent under a slight load, it has now acquired considerable stiffness and rigidity. What is the reason of this? The point P could formerly be pressed downwards a little without breaking the beam, and on the relaxation of the pressure it returned, of course, to the horizontal line. Let us suppose that it could be pressed down to P′. P P′ is vertical, for the ends A and B being secured, P could not be pushed either towards A or B, but only vertically. In the triangle C P P′ the angle C P′ P is the greatest, and therefore C P is greater than C P′. Hence P cannot be depressed at all without coming nearer to C; but when the rod C P is introduced, and firmly fastened both at C and P, it prevents P coming any nearer to C, and therefore P cannot move at all, provided the joint do not slip nor the pressure be sufficient to break C P. In fact, A P C may be looked upon as a triangle on the base A C; and since, by Euclid I. 7, there cannot be two triangles on the same base and same side of it which have their conterminous sides equal, it follows that P cannot move when C P is applied, though the flexibility of the wood would have allowed it to do so previously. In precisely the same way it can be shown that Q is a fixed point. Hence the beam A B may be regarded as directly supported at P and Q, and therefore the whole will be as strong as each of the three equal segments into which it is divided. Hence, by the principle already explained, the strength of the bridge is increased threefold. Actual experiment will be found to justify this reasoning. By placing a second four-feet rod parallel to A B, and distant from it by a few inches, and similarly supporting it by two other rods, and then laying a few short rods crossways over both beams to form a roadway, the bridge can be loaded with weights to test its strength.

THE ARCH.

The simplest theory of the arch is that which is given by Dr. Hooke. A chain which is suspended from two points hangs downwards in a curve called the *catenary*, and each of its links is retained in equilibrium by the tension of the two adjacent links which counterbalance its weight. Precisely similar is the equilibrium of the stones which form an arch. Each of the stones is held in equilibrium by the pressure of the two adjacent stones, called voussoirs, and its own weight. The difference between the cases is, that while the equilibrium of the chain is unstable that of the arch is stable.

NOTABLE INVENTIONS AND INVENTORS.

VII.—THE MARINER'S COMPASS (*concluded*).

BY JOHN TIMBS.

We now resume the history of the compass. In 1280, when Marco Polo returned from his travels in Cathay, he is believed to have brought a knowledge of the compass, as well as other Chinese inventions, back to Europe with him; but there is no known authority for this opinion that can lay claim to authenticity. It is certain, however, that before the close of the fifteenth century, when Vasco de Gama found his way round the Cape of Good Hope, the pilots of the Indian seas were expert in the use of sea-charts, the astrolabe, and the compass.

We find the compass minutely described by Guyot de Provence, in his satire, "Le Bible," about the year 1190. Guyot, a minstrel by profession, had probably seen it in use during the Crusades, to one of which, most likely, he had previously attached himself. At all events, Cardinal de Vitry and Vincent de Beauvais, both Frenchmen, and both Crusaders, writing at a later period by a quarter or half a century than Guyot, speak of it as a great curiosity which they saw in the East, and we may infer that it was a thing almost unknown in Europe. There is not, hence, the slightest foundation for the belief that it was used by European seamen at so early a period, though there can be but little doubt that by the middle of the thirteenth century it had come into partial use, and into general knowledge; since, in one of the songs of Gauthier d'Epinoir, is an *allusion* which no one would have made, had not his auditors been familiar with the magnetic needle.

It was long contended that the inventor of the compass as a nautical instrument was Flavio Gioja, a native of Amalfi, near Naples; and the date given by the Italians is from 1300 to 1320. It is obvious, from what we have already said, that there is no foundation for this opinion. Before this assigned period, even the "Tresor" of Brunetto Latini (the master of the divine Dante) bears evidence that the compass was not a rarity. It is, however, highly probable that Gioja greatly improved the compass, either by its mode of suspension, or by the attachment of the card to the needle itself, or in some other important particular.

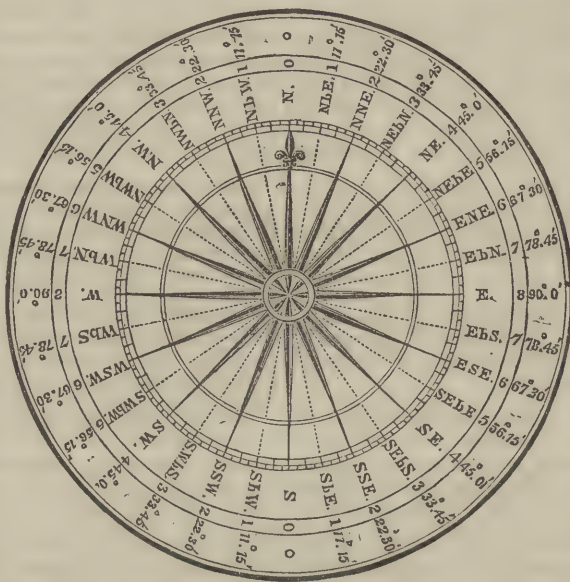
The French long laid claim to the discovery of the compass, or at least to the attachment of the card to the needle, from the circumstance of the north point being marked with the *fleur-de-lis*; but there is no distinct evidence on this point, and Sir John Davis, with more probability, considers that the figure is an *ornamental cross*, originating in the devotion of an ignorant and superstitious age to the mere symbol. Besides, this ornament is not peculiar to the compass, but may be seen on the hour-hand of modern French clocks. Or, as Sir John observes, "as the compass undoubtedly came into Europe from the Arabs, the *fleur-de-lis* might possibly be a modification of the *monasala* or dart, the name by which the Arabs called the needle." Still, the *fleur-de-lis*, as the ornament of the northern radius of the compass, is said to have been adopted by Gioja, the Neapolitan, because it was the device of the reigning King of Sicily at the time Gioja first employed the instrument in navigation.

By whom the suspension now generally used was invented, is altogether unknown from any document or other evidence. We have already explained that a magnetic needle balanced on a pivot will, subject to a correction for the variation of the magnet, point out the true direction of *north* and *south*. A card, bearing the points of the compass, and unalterably attached to any apparatus, such as a globe, will therefore afford the means of adjusting it north and south, if the centre of the card be made the pivot of a magnetic needle. In the mariner's compass, however, we affix the needle to the card, pointing it towards north and south, so that the card travels with the needle; and if a pointer (fixed with respect to the ship) mark out the point on the edge of the card, which lies in the line drawn through the pivot parallel to the plane which symmetrically bisects the ship, the bearing of the ship's head is shown by that part of the card to which the pointer directs for the time being. To ensure the horizontality of the compass-card, the cylindrical box in which it is enclosed is supported in a hoop at opposite points by pins projecting from it, so as to allow the box to revolve inside the hoop. This hoop is supported in the same manner on pivots, the line of which is at right angles to the first points; so that by the rotation of the compass-box in the hoop, and of the hoop itself, the former can always form its position of equilibrium, which is

the horizontal position. The small oscillations of the apparatus are immediately destroyed by the friction. The apparatus is then said to be supported on gimbles, or gimbals, allowed to have been the invention of an Englishman.

The *dip of the needle*—that is, the angle which, when supported on its centre of gravity, it makes with the plane of the horizon—was discovered by Robert Norman, of Wapping, in 1594. Next was discovered the variation of the compass; that is, that it did not point directly to the north, but somewhat east of that point. To account for this it was supposed that the magnetic pole of the earth did not coincide with that of the axis on which the globe itself turned, and so it proved.

The *variation of the needle* was known to a Chinese philosopher, who wrote about the year 1111. Columbus was sailing across the Atlantic Ocean, in his attempt to find a new world. On September 13, 1492, in the evening, being about two hundred leagues from the island of Ferro, Columbus first noticed the phenomenon: the variation was a little to the west at London. About nightfall, the needle, instead of pointing to the North star, varied about half a point, or between five and six degrees to the north-west, and still more on the following morning. Columbus was struck with the circumstance, and he observed the variation to increase three days as he advanced. He at first made no mention of the phenomenon, knowing how ready now his people were to take alarm; but the pilots were filled with consternation. It seemed as if the very laws of Nature were changing as they advanced, and that they were entering another world subject to unknown influences. They apprehended that the compass was about to lose its mysterious virtues, and without this guide what was to become of them in a vast and trackless ocean! Columbus now sought to allay their terrors. He told them that the direction of the needle was not to the Polar star, but to some fixed and invisible point; the variation was not caused, therefore, by any fallacy in the compass, but by the movement of the North star itself, which, like the other heavenly bodies, had its changes and revolutions, and every day described a circle round the pole. The pilots had faith in Columbus, and believed him. His explanation, as the Copernican system was unknown, was plausible, and was believed; and it showed Columbus's readiness to meet the emergency. The phenomenon has now become familiar to us, but we are not so cognisant of its cause. "It is," says Washington Irving, "one of those mysteries of Nature open to daily observation and experiment, and apparently simple from their familiarity; but which, on investigation, make the human mind conscious of its limits, baffling the experience of the practical, and humbling the pride of science."



THE MARINER'S COMPASS.

The iron employed so extensively in modern vessels has created great, but generally unsuspected, deflections of the magnetic needle from the position which, under the influence of terrestrial magnetism only, it would take in any given place and at any given time. Numerous vessels have been wrecked in consequence of this alone. In England, the errors of the compass from the action of iron have been corrected by placing near it powerful magnets, the action of which produces upon the needle equal effects, but opposite to those of the ship. The French employ a table of corrections, based upon minute observation, and applicable to every indication of the compass affected. Nevertheless, fatal accidents are still attributable to the errors of the compass. One of the contrivances for diminishing this serious inconvenience is the correcting compass, which affords the means of taking the sun's position, whereby the deviation may be corrected. Lightning alone exercises a decided influence on the needle, by reversing its points, so that north becomes south, and conversely. When a vessel is nearing land, the needle is said to be affected; and certain rocks exercise a decided magnetic influence on the compass, volcanic rocks especially, but this influence is not felt on board ships. But the action of the iron forming the ship's sides is far different; nothing, not even the interposition of a thick non-magnetic body, will stop its influence. But the real danger proceeds from another source; since the ship herself, under her weight of canvas, may increase the deviation of the needle. From experiments made on board an iron-built sailing vessel, provided with iron rigging and lower yards of steel, and with two binnacle compasses on her poops, and a third placed between the mizen and main-masts, the lower part of which was all of iron, the deviations of the needle were respectively 56°, 24°, and 35°. It need scarcely be added that much experience may be gained by freighting an iron vessel only when she has been at sea for a considerable time, in order to ascertain how her compass behaves. The Rev. William Scoresby, whom we have already mentioned, published his various investigations of the influence of iron ships upon their compasses, and the requisite corrections. One of the most interesting of these we have described in the previous number. In 1855 Dr. Scoresby communicated to the British Association a summary of his matured views and the evidence in their favour, in which he recalled attention to his plan of *a compass aloft*, which affords a simple and effective mode of ascertaining the direction of a ship's course; and to exemplify this and other questions, Dr. Scoresby, in 1856, took a voyage to Australia in the *Royal Charter* iron steam-ship. His theory proved correct. But the fatigue of the voyage to a man approaching seventy years of age was excessive, and, without doubt, accelerated his death. As a proof of his energy in the cause of science, it may be mentioned that once in the course of this voyage, in a violent cyclone, he ascended the mizen-rigging to judge of the height of the waves, which he calculated to be then thirty feet. He returned to England, and narrated his voyage to a large audience at Whitby; but while preparing his journal for publication he died, leaving his widow to receive, as a memorial of his services, a chair formed from timber of the vessel in which he made his voyage to Australia.

In reviewing the history of the compass, we are reminded of the remark of Sir John Herschel—that such inventions are not the creation of a few years, or a few generations. They presuppose long centuries of previous civilisation, and that, too, at the dawn of European history, when the declination of the needle was known.

The following facts relative to the construction of the mariner's compass, the graduated card of which is shown in the annexed illustration, may prove interesting to the reader:—The shape of the needle is generally that of a long parallelogram, of which the width is very small in comparison with the length; or that of an elongated lozenge. A hollow cone, generally of steel, but sometimes of agate, rises precisely in the centre of the needle to supply the means of balancing it on the fine point of the pin on which it works, and about which it may turn freely in any direction without the slightest hindrance from friction.

The pin on which the needle works rises perpendicularly from the centre of a circular card, marked as in the illustration. The central portion of the card, lying within a graduated ring divided into 128 parts, is marked with a star of 32 rays, of

which 16 are solid and 16 dotted. These rays mark the 32 points of the compass, the ray that marks the north point on the card being distinguished by a *fleur-de-lis*. The graduated ring already spoken of shows the division of each of the 32 points into quarter-points. In the ring or belt immediately without it is marked the reading of each point. In the narrow ring immediately without this is marked the numerical order of the points from north and south to east and west on either side; and in the outermost ring is given the value of each point from north and south to east and west on either side in degrees and minutes, each point being equal to the 1-32nd part of 360 degrees, or 11° 15′.

ANIMAL COMMERCIAL PRODUCTS.—XIV.

III.—EDIBLE SPECIES.

THE preceding notice of the Mollusca would be incomplete without some reference to their value as a source of human food. Amongst the edible kinds we have the

Oyster (*Ostrea edulis*).—Vast beds of this mollusk are planted and tended with great care. The oyster culture is carried on most extensively at Colchester and other places in England, and on the coasts of France. The oysters are laid in beds, in creeks near the shore, where in two or three years they grow to a considerable size, and improve in flavour. Between 14,000 and 15,000 bushels of Essex oysters are consumed in London annually. There are 200 vessels, of from twelve to fifty tons' burden, manned by 400 or 500 men and boys, continually dredging for oysters on the Essex coast.

Mussel (*Mytilus edulis*).—This is another popular mollusk, not so digestible as the oyster, but nevertheless in considerable demand as human food, and largely employed as bait for whiting, haddocks, and cod. We have also the *Cockle* (*Cardium edule*), *Periwinkle* (*Littorina littorea*), *Whelk* (*Buccinum undatum*), and the *Ormond Whelk* (*Fusus antiquus*), with which our markets are abundantly supplied. Others might be mentioned, but enough has been said to show that, whilst the shell of the mollusk is attractive and useful, the soft body of the creature that dwells within it is not less valuable.

PRODUCTS OF THE SUB-KINGDOM ANNULOSA.

Annulosa (Latin, *annulus*, a ring), a name given to the third great division of the animal kingdom. The body, in *Annulosa* generally, presents a symmetrical form, and consists of a series of rings or segments; the nervous system is a double nervous thread, which extends along the body at its lower side, and is united at certain distances by double "ganglia," as these nervous masses are termed—nerves being given off from these ganglionic masses. In the group *Annuloida*, the body is ringed and devoid of limbs, whilst in the *Articulata* it is composed of móvable pieces, and the limbs are jointed.

The Annulosa are divided into the following classes:—

1. *Annelida* (Latin, *annulus*, a little ring), animals having bodies soft and pliable, more or less cylindrical, and formed of a great number of small rings. Examples: earthworm and leech.

2. *Crustacea* (Latin, *crusta*, a hard covering), having an articulated, hard shelly case or covering, in which the softer parts of the body are contained. Examples: crabs, lobsters, etc.

3. *Arachnida* (Greek, *arachne*, a spider), having the head and thorax confluent with each other, and the body consequently consisting of only two segments, with eight legs, and smooth eyes. Examples: spider and scorpion.

4. *Insecta* (Latin, *in*, into, and *seco*, I cut), including those animals having an insected or divided appearance of the body into three well-marked portions, called respectively the head, thorax, and abdomen. Six legs are articulated with the thorax. Examples: bee, moth, and beetle.

In the first class, *Annelida*, we have one species of very considerable value in commerce, the

Leech (*Hirudo medicinalis*, L.).—This is an abranchiate red-blooded worm, provided with a circular disc or sucker, at either extremity of the body. The oval aperture or mouth is formed of three pairs of cartilaginous jaws, each armed with two rows of very fine teeth, and disposed in such a manner that they form three radii of a circle. This apparatus enables the leech so to penetrate the skin as to ensure a ready flow of blood without causing a dangerous wound. Leeches are usually found in pools and marshes, sometimes in England, but principally on the Continent, especially in Portugal, the south of France, Germany, Hungary, and Russia. The greatest quantities come through Pesth and Vienna from Hungary. Most of the leeches used in England are imported from Hamburg, whither they are sent from the lakes of Pomerania and Brandenburg, and from the province of Posen in Prussia.

Leeches are taken by men, who wade into the pools with naked legs, to which they fasten themselves. The men then leave the water, and remove them before their bites become injurious. Leeches are sent over in bags, or more frequently in small tubs, closed with stout canvas to allow a free passage of air. Each tub usually contains about 2,000 leeches. Some idea of the extensiveness of the leech trade may be obtained from a fact mentioned by Dr. Pereira, that, some years ago, "four principal leech dealers in London imported on the average 600,000 leeches monthly, or 7,200,000 annually." The annual consumption of leeches in Paris is estimated at 3,000,000, and that of the whole of France at 100,000,000.

The second class, *Crustacea*, furnishes several species which are used as food—as crabs, lobsters, crayfish, prawns, and shrimps, so well known as to render description needless. Omitting the Arachnida, which are of no commercial value, we come to the fourth class, *Insecta*, which is pre-eminent over the others in the number of individuals, and in their beautiful forms, colours, and transformations. Its members are in the highest degree valuable to man, furnishing him with unlimited supplies of honey, wax, silk, and dyeing materials. The following are the most important insects, regarded from a commercial point of view.

The *Silkworm Moth* (*Bombyx mori*) belongs to the family *Bombycidæ*, a section of the nocturnal lepidoptera or moths. It has short plumose antennæ, a thick short body, stout legs, and white wings, with two or three dark lines stretching across them parallel to the margin. It lays its eggs, which are of a greyish tint, on the leaves of the mulberry tree (*Morus alba*), upon which the larva feeds. These larvæ form the cocoons from which the silk is procured. The eggs may be preserved a long time without deteriorating, provided they are kept free from damp, and not too many in the same packet. The eggs in this state are called by the silk cultivators "seed."

The larvæ when first hatched are a quarter of an inch long and of a dark colour, and the first care after their birth is to separate them from their shells, and place them in hurdles where they may find appropriate food. For this purpose, a paper perforated with holes and covered with mulberry-leaves is spread over the basket in which the larvæ are placed, and in passing through the holes to get at the mulberry-leaves, they free themselves from their shells. The silkworm lives in the larval state from six to eight weeks, during which time it moults or changes its skin four times, increasing in size and voracity with every moult, and when fully grown is about three inches in length.

The caterpillar now stops eating, betakes itself to some convenient spot where, after spinning a few threads in various directions, it suspends itself in the midst of them, and by continually twisting its body, it gradually envelopes itself in a thick, silken, oval-shaped cocoon. The silk is a secretion of a pair of tubes called *sericteria*, which terminate in a prominent pore or spinneret on the under lip of the caterpillar. The two fine filaments from the *sericteria* are glued together by another secretion from a small gland, so that the apparently single silken thread proceeding from the caterpillar, which forms the cocoon, is in reality double. Whilst spinning the cocoon, which is usually completed in five days, the larva decreases in bulk, casts its skin, becomes torpid, and ultimately assumes the chrysalis form in the interior of the cocoon.

The cocoons, when completed, are thrown into warm water, which dissolves the glutinous matter that causes the threads to adhere, and separates them. The end of the thread is then found, and placed upon a reel; the silk is wound off the cocoon and formed into hanks. When this is carefully done, the silken thread obtained from a single cocoon is sometimes from 750 to 1,150 feet long, or of an average length of 300 yards. Twelve pounds of cocoons yield 1 pound of raw silk. About 1 ounce of silkworms' eggs will produce 100 pounds of cocoons; 16 pounds of mulberry leaves are food sufficient for the production of 1 pound of cocoons; and each mulberry tree yields about 100 pounds of leaves. These data afford the reader the means of cal-

culating the number of insects, eggs, trees, and leaves necessary for the production of 6,000,000 or 8,000,000 pounds of silk, the quantity that is annually consumed in the United Kingdom.

The art of rearing silkworms, of unravelling the threads spun by them, and manufacturing those threads into articles of dress and ornament, seems to have been first practised by the Chinese. In China, Japan, and India, silk has formed, from time immemorial, one of the chief objects of cultivation and manufacture. The silkworm moth and the mulberry tree are, in fact, both natives of China, and a great portion of our supplies of silk is still derived from that country. There was a time when silk, now so abundant, was valued in Rome at its weight in gold, and the Emperor Aurelian refused his empress a robe of it on account of its dearness. At the period when our ancestors were naked savages—2,000 years ago—the Chinese peasantry, amounting in some provinces to millions in number, were clothed in silk.

From China the cultivation of silk extended to Hindostan, and thence to Europe, in the reign of the Roman Emperor Justinian, about the middle of the sixth century. From the sixth to the twelfth century the culture of silk was confined to Greece, particularly to the Peloponnesus, where it spread so much that this part of Greece derived its modern name, Morea (Latin, *morus*, a mulberry), from that circumstance. From Greece silk cultivation spread into Sicily, Italy, Spain, and finally France. The French commenced its culture in 1564, under the auspices of Henry IV., and the raising of raw silk and its manufacture now forms a very considerable proportion of the French trade. We have not space for further detail of the progress of the silk manufacture.

At present the United Kingdom is supplied with the raw material for manufacture principally from China, the East Indies, the Levant, France, and Italy. Of Chinese silks the best come from the provinces of Nankin and Tsekiang in Eastern China. Silk of an inferior character is received from Southern China, through Canton. The principal ports from which we receive East Indian silk are Calcutta and Bombay. The exports from these places amount to 10,000 cwt. annually. Anatolia and Syria produce much good silk, principally around Damascus and Beyrout; this goes chiefly to Western Europe, *viâ* Aleppo, Smyrna, and Constantinople. A great deal of Persian and Armenian silk is brought by caravans from Asia, by Bassora, Bagdad, Damascus, etc., to the ports of the Levant, and goes by the name of silk of the Levant. This name also includes all the silk produced in Turkey, the Morea, and in the Archipelago, and brought into commerce through Gallipoli and Salonica. As the breeding of silkworms only prospers in warm climates, silk culture is confined in Europe to Italy, the South of France, and Spain. There is also considerable silk cultivation on the southern slopes of the Alps, in Tyrol and Illyria, and within the last twenty years successful attempts at silk culture have been made in Bavaria and Lower Austria.

A SILKWORM-REARING ESTABLISHMENT.

The quantity of raw silk imported into this country in 1865 was nearly 8,000,000 pounds, and the value of the same manufactured was estimated at more than £17,600,000. Although the climate of England is too cold to enable us to rear the silkworm, we are able to manufacture the silk. We have upwards of 300 silk manufactories, giving employment to 50,000 hands. The principal seats of the English silk manufacture are:—For broad silks, Spitalfields, Manchester, Macclesfield, Glasgow, Paisley, and Dublin; for crapes, Norfolk, Suffolk, Essex, Middlesex, and Somerset; for handkerchiefs, Manchester, Macclesfield, Paisley, and Glasgow; for ribands, Coventry; for hosiery, Derby; and for mixed goods, Norwich, Manchester, Paisley, and Dublin. The annual value of the goods manufactured is computed at £10,000,000. The exports of British manufactured silks are chiefly to the United States and the colonies. We also ship silks extensively to South America, Germany, Belgium, and even India and France.

Next to the silkworm moth the *Honey Bee* (*Apis mellifica*)

is the most useful insect to man. This insect belongs to the order *Hymenoptera* (membrane-winged), an order characterised in most of the genera by the presence of a sting. The habits of the honey bee are replete with interest, arising from its social economy and from the separation of the individuals into three communities based on sexual modification, viz., the queens, or prolific females; the workers, or barren females; and the drones, or males.

The hive bee or honey bee is distinguished from the other species of *Apis* by having the femora of the posterior pair of legs furnished with a smooth and concave plate on the outer surface, which, fringed with hair, forms a basket adapted for the conveyance of pollen. A swarm of bees consists generally of about 6,000 individuals, of which about one-thirtieth part are males, the rest females, and of these one only is for the most part prolific, called the "queen." The body of the queen bee is longer, her colours brighter, and her head smaller than these parts in the other bees, and her sting is curved. The male bees or drones have no stings; their body is shorter and thicker. The workers have a straight sting, but as their growth is arrested before the full development of all their organs, they are smaller than either the queen or the drones, and their colours are less bright. The honey bee in its natural state generally constructs its nest in hollow trees, but throughout Europe it is now rarely found except under domestication.

The comb consists of beautiful hexagonal cells, placed end to end in such a manner that each cell is closed by three waxen plates, each of which also assists in completing one of the cells of the other side of the comb. The whole duty of the construction of the comb and the care of the young devolves upon the workers, whose incessant activity has rendered them the symbol of industry.

It is a remarkable fact that we derive the greater part of our knowledge of the economy and habits of the hive bee from the labours of a blind man. The elder Huber lost his sight when only seventeen years of age, but by means of glass hives, variously constructed, he was enabled, through the aid of his wife, to become acquainted with all that was going on in them, and from her faithful recital of what she saw, together with the aid of an untiring investigator, M. Burnens, he amassed the material for his celebrated work.

In the construction of the comb the bees take hold of each other, and suspending themselves in clusters, which consist of a series of festoons or garlands crossing in all directions, remain immovable for about twenty-four hours, during which time the wax is secreted in the form of thin plates from between the scales of their bodies. One of the bees makes its way to the roof of the hive, and detaching its plates of wax in succession from the abdomen with the hind legs, works them up with the tongue into the material which forms the comb; this bee is followed by others, which carry on the work. As soon as a few cells are thus prepared, the queen bee begins to exude her eggs. The first eggs develop into workers, the next produce the drones and also the queens. The eggs are deposited in the cells, and in five days the maggot is hatched. The sole employment of the queen bee is the laying of these eggs, and as only one is deposited in each cell, this occupies her almost incessantly. The queen, when thus engaged, is accompanied by a guard of twelve workers, who clear the way before her, and feed her when exhausted, always with the utmost courtesy turning their faces towards her, and when she rests from her labour, approaching her with humility. She "lays workers' eggs for eleven months, and afterwards those which produce drones. As soon as this change has taken place, the workers begin to construct royal cells, in which, without discontinuing to lay the drones' eggs, the queen deposits, here and there, about once in three days, an egg which is destined to produce a queen. The workers' eggs hatch in a few days, and produce little white maggots, which immediately open their mouths to be fed; these the workers attend to with untiring assiduity. In six days each maggot fills up its cell, it is then roofed in by the workers, spins a silken cocoon, and becomes a chrysalis, and on the twenty-first day it comes forth a perfect bee. The drones emerge on the twenty-fifth day, and the queens on the sixteenth."*

* "Familiar Introduction to the Study of Insects." By Edward Newman, F.L.S.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

VIII.—JAMES HORSBURGH, F.R.S.

BY JAMES GRANT.

JAMES HORSBURGH, the distinguished hydrographer, whose works and discoveries won for him the justly-merited title of "The Nautical Oracle of the World," was a native of the county of Fife, a district singularly prolific of illustrious Scotsmen, even from an early period. He was born on the 23rd of September, 1762, in the little town of Elie, which in those days was a place of some importance, as the massive and ancient mansions which stand near its beach remain to testify. As his parents were in humble rank, his education at the parish school was varied by labour in the fields; but, like many of those who live upon the Fifeshire coast, being destined for a nautical life, his education was directed with that view. He acquired the elements of mathematical science, book-keeping, and the theoretical parts of navigation, and at the age of sixteen went to sea as a cabin-boy, being bound apprentice for three years. He served in various vessels, chiefly in the coal trade, and made many trips to Newcastle, Ostend, Holland, and Hamburg. In May, 1780, a temporary interruption was put to these little voyages, by the vessel in which he served being fired upon and captured, when off Walcheren, by a French war-ship of twenty guns, the captain of which placed him and all his shipmates in prison at Dunkirk. After being liberated by an exchange of prisoners, he made a voyage to the West Indies, and another to Calcutta in 1784. There, by the influence of Mr. D. Briggs, an eminent shipbuilder, he was made third mate of the *Nancy*, bound for Bombay, and during the two subsequent years he continued trading along the coast of India.

In May, 1786, he was first mate of the *Atlas*, which was bound from Batavia to Ceylon. In his then capacity, he was regulating the ship's course by the charts at that time authorised and in use, when she was wrecked in the night on the lonely island of Diego Garcia. According to its bearings on the chart, Horsburgh believed himself in the open sea, when the crash of his ship upon the rocks showed that he was trusting to a worthless guide; and but for this event, and the impression it made upon his mind, he might have remained to the end a hardy, skilful, and enterprising mariner, but nothing more; so "the loss of this vessel was repaid a thousandfold, by the effects it produced." He learned the imperative necessity for having more correct maps of the Indian sea than the world then possessed, and he resolved to supply this want himself, by making, and committing to paper, his nautical observations. From the day the resolution was put in practice, he rapidly accumulated a store of notes on the bearings of the Indian coasts and isles, which served as the materials for his future works on hydrography.

On his return to Bombay, where he arrived a penniless, poor, and shipwrecked sailor, he immediately looked out for another vessel, and soon shipped on board the *Gunjana*, a large Indiaman employed in the China trade; and for several years he sailed with her and the *Anna*, in the capacity of first mate, and made many voyages between Canton, Bombay, and Calcutta; but he never forgot the resolution he had formed after his misfortune at Diego Garcia; and "he was clever enough to see that the great objects in life are accomplished less by dexterity and address than by a strong and undeviating purpose." His notes and observations had increased to a mass that only required arrangement. By the most careful study he had perfected himself in the whole theory of navigation, especially that portion which bore on Oriental hydrography; he had familiarised himself with lunar observations; and during the short intervals of his stay in harbour had taught himself the mechanical part of his future occupation by drawing and etching. During two of the voyages which he made to China by the Eastern route, he constructed three charts, one of the Strait of Macassar, between the isles of Borneo and Celebes; another of the western coast of the Philippine Isles; and a third, of the tract from Dampier's Strait, through Pitt's Passage, towards Batavia; and all these were accompanied by practical sailing directions. These charts he presented to an old friend and shipmate, Thomas Bruce, then at Canton, where they were shown to several Indian captains, and to Colonel John Drummond (son of Viscount Strathallan, who fell in the Prince's cause at Culloden), then at the head of

the English factory in Canton. By his influence they were published in London, under the patronage of the Court of Directors of the East India Company, for the use of their ships. The Court also presented a letter of thanks to their author, together with a handsome sum of money, to enable him to procure some nautical instruments of which he was much in want.

When first mate of the *Carron*, he returned to Britain in 1796, and the excellent trim in which he kept that ship won him great praise from several naval men, while his scientific acquirements procured him the acquaintance of Sir Joseph Banks, Mr. Dalrymple, hydrographer to the East India Company, Dr. Maskelyne, the Astronomer Royal, and other men of science. He was now employed to convey troops to Porto Rico and Trinidad, after which he quitted the *Carron*, and in 1798 was made captain of the *Anna*, his old ship, and with her made many more voyages between China, Bengal, and London, his nautical notes being daily and nightly—even hourly—his peculiar care. From the 1st of April, 1802, to the middle of February, 1804, he kept a register *every four hours* of the rise and fall of the mercury in two marine barometers, and found "that while it regularly ebbed and flowed twice during the twenty-four hours in the open sea, from latitude 20° N. to 26° S., it was diminished, and sometimes wholly obstructed, in rivers, harbours, and straits, owing to the neighbourhood of the land." This important discovery he transmitted to the Royal Society, and it was published in their "Philosophical Transactions" in 1805. At Bombay he became proprietor of a valuable astronomical clock belonging to one of the French vessels which had been sent in quest of the lost voyager, the unfortunate La Perouse, and regulating his own chronometers by it, he was enabled to make many valuable observations on the satellites of Jupiter; and these he forwarded to the Greenwich Observatory. About the same time he prepared a chart of the Strait of Allas, a dangerous channel through the Sunda chain of islands between Lombok and the west coast of Sumbawa; and this and other surveys were immediately engraved for the use of seamen sailing in those seas.

Captain Horsburgh was now urged to publish, for his own pecuniary benefit, the result of his observations and discoveries; but the expense seemed too great for a mere master mariner, and might dissipate all his savings, then amounting to £6,000. Returning to London in 1805, he published by subscription "Directions for Sailing to and from the East Indies, China, New Holland, the Cape of Good Hope, and all adjacent ports," the result of twenty-one years' hard experience in the Southern and Eastern seas. So correct were some of the charts in this publication, that their very accuracy nearly marred their production; for with such care and minuteness "were the bearings of Bombay harbour laid down, that it was alleged they would teach an enemy to find the way in, without the aid of a pilot. It was no wonder, indeed, that these were so exact, for he had taken them with his own hands during whole weeks in which he had worked from morning till night, under the fire of a tropical sun."

In the same year of this publication occurred his marriage, by which he had a son and two daughters. In 1806 he was made a Fellow of the Royal Society, and four years afterwards was appointed, on the death of his friend Dalrymple, hydrographer to the East India Company, and he now devoted his whole energies to the construction of those charts which still continue to be the text and standard of our Eastern ocean navigation. In 1816 he published "An Atmospherical Register for indicating Storms at Sea," together with a new edition of "Mackenzie's Treatise on Marine Surveying." In 1819 he published his "East India Pilot," and contributed to the Royal Society a Paper on the "Icebergs of the Southern Hemisphere." In 1835 he published a "Chart of the East Coast of China," drawn from personal observation, having the names of all the localities in Chinese characters, and in English, translated by himself; and this was his last work. For six-and-twenty years after the date of his appointment as hydrographer, he was indefatigable in the great cause of humanity, preparing and correcting charts—true to the vow he had made on that night when the *Atlas* perished on the rocks of Diego Garcia; and to that cause he may be said to have fallen a martyr, for the long hours he spent in the cold, damp vaults of the India House, poring over and comparing scientific documents, maps, plans, and charts, together with his enthusiasm in, and general close study of, the science of hydrography, broke down a constitution that was otherwise robust and hardy. His last labours were addressed to the publication of a new edition of his favourite work, "Directions for Sailing to and from the East Indies, etc;" with many additional notes; he had it all ready for the press, save the index, when Death laid his hand upon him; and in his last illness he said to his friend and patron, Sir Charles Forbes, "I would have died contented, had the blessed God been but pleased to allow me to see *that book* in print;" and his last words were about the disposal of his works, so that they might be made available for more extended usefulness, as guides for all ships at sea; and to this charge the Directors of the East India Company honourably acceded, taking care in the meanwhile that his children should benefit by the arrangement.

On the 14th of May, 1836, he died of hydrothorax, in his seventy-fifth year; and a striking public acknowledgment of his great merit is contained in the report of shipwrecks (by a Select Committee of the House of Commons), which refers to the highly valuable labours of the East India Company's maritime officers, and the "zealous perseverance of their distinguished hydrographer, the late Captain Horsburgh, whose Directory and charts of the Eastern seas have been invaluable safeguards to life and to property in those regions." It is pleasing to add that the lessons he received from his pious old father, before he left his native place in the humble post of a cabin-boy, were never forgotten by him in all his subsequent career, as he "was ever distinguished by the virtues of gentleness, kindness, and charity; and even amidst his favourite and absorbing studies, the important subject of religion employed much of his thoughts."

He wrote several treatises in defence of church establishments, and a few months before his death he published a pamphlet on polemic theology, entitled "A National Church Vindicated."

Such was the useful career of this distinguished merchant-mariner.

TECHNICAL DRAWING.—XXII.

DRAWING FOR MACHINISTS AND ENGINEERS.

PROJECTION AND DEVELOPMENT.

In this plate the projection and development of a cylinder, penetrated by two other cylinders at different angles, are shown.

Fig. 220 is the elevation of the object, of which it is required to project the plan.

Draw a horizontal line in the lower plane, and from A and B of the elevation drop perpendiculars meeting it in A′, B′ (Fig. 221); then the distance between these two points will be the entire *length* of the ground covered by the object.

Now to find the width of the plan, draw the central line or axis in the elevation, C D, and from C and D draw perpendiculars passing through the line A′ B′ in *c* and *d*.

The line *c d* is then the plan of the axis.

At any part of the axis of the elevation describe a circle equal to the true section of the cylinder, and through its centre draw *e f* at right angles to C D.

On each side of *c* and *d* in the plan set off the length of the radius of the circle, *o d*′, *o d*″—viz., *c* C′, *c* C″, and *d* D′, *d* D″.

Draw C′ D′ and C″ D″, which will give the width of the straight part of the cylinder.

Now it must be remembered that the circle drawn at O represents the section at *right angles* to the axis, which for the present purpose is supposed to be rotated on *e f*, and this will explain the following process:—

Divide the circle into any number of equal parts in the points *k*, *i*, *d*′, *g*, *m*, etc.; then the length of the line joining the points, as *m n*, which are opposite to each other, will represent the width of the cylinder at that part as it would be seen on looking down upon it.

Therefore, through *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n* draw lines parallel to the axis of the cylinder and cutting the end of the cylinder in *m*′ *n*′, *g*′ *h*′, *i*′ *j*′, and *k*′ *l*′.

From these points drop perpendiculars passing through the plan, and on them from the central line, A′ B′, set off the lengths of the lines drawn across the circle, measuring from the line *e f*; thus, *g*″ *h*″ and *i*″ *j*″ in the plan will be the same length as the lines *g h* and *i j* in the circle *o*, etc. Through these points the ellipse is to be drawn, which is the horizontal section of the cylinder at this angle, and here seen in plan.

It is scarcely necessary to mention that the end on which

the cylinder rests—viz., A E—will be projected in precisely the same manner, and the same working lines will serve for the one end as well as for the other.

Thus, from the points where the lines drawn through *m*, *n*, *g*, *h*, etc., in the circle *o* cut the line A E, drop perpendiculars, which, being intersected by horizontals drawn from the points correspondingly lettered in the plan, will give the points through which the ellipse of the lower end is to be traced; one-half of this being hidden when looking down upon the object, it is drawn in dots.

It is now required to project the plan of the cylinder, G H I J, which penetrates the original object, and it will at once be will give the ellipse representing the plan of the circular end, H I.

The projection of the upright cylinder, by which the longest one is penetrated, and on which it rests, is obtained in the same manner, and it is believed that the student will be able to work this without instructions, observing that the plan in this case is a circle.

We now proceed to show the method of finding the exact shape of the sections, or surfaces at which the cylinders touch each other at their penetration; and as all are executed on the same principle, it will be sufficient to demonstrate the process on one section—that at O P.

Fig. 220.

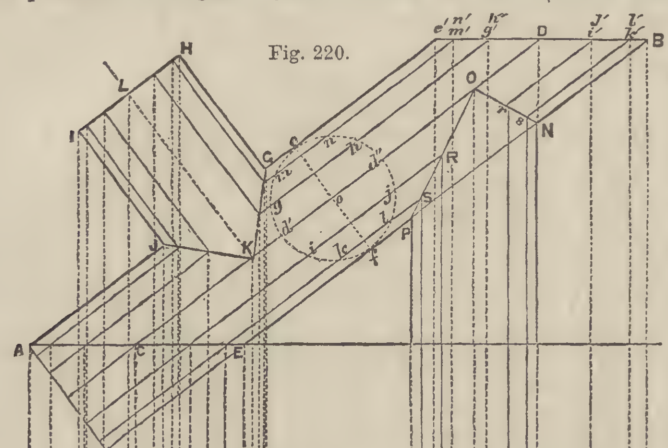


Fig. 221.

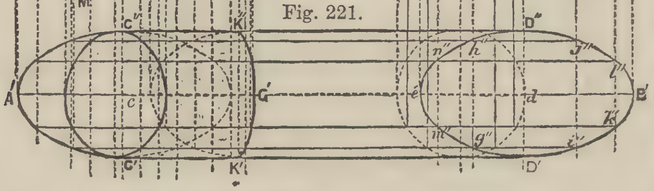


Fig. 225

Fig. 227.

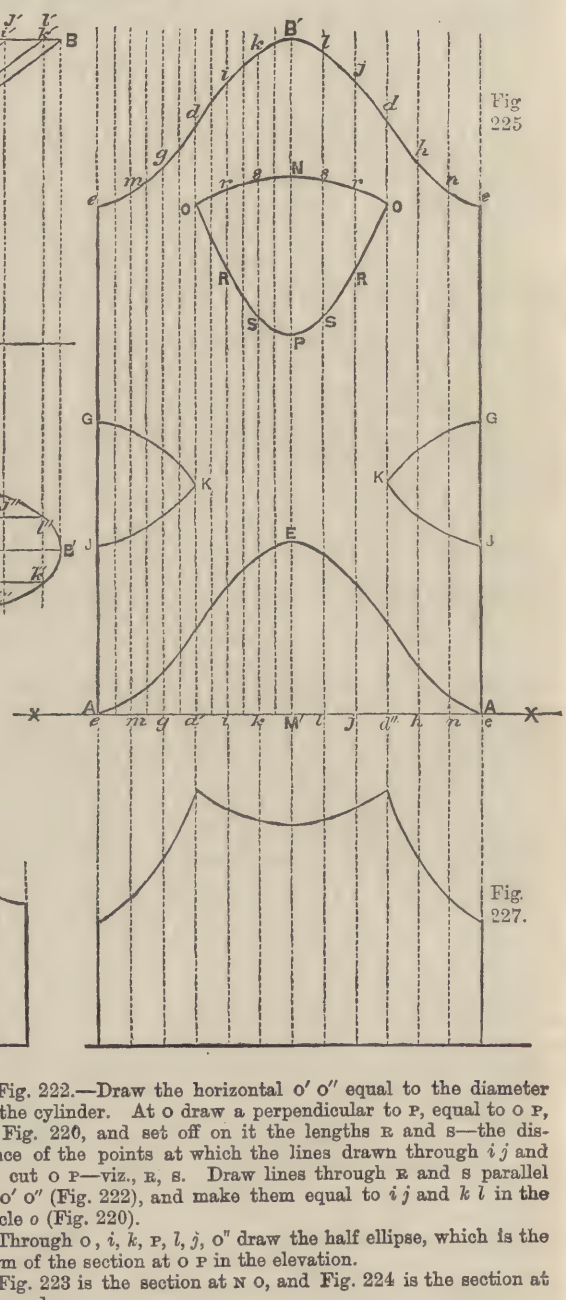


Fig. 224.

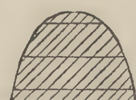


Fig. 223.

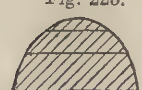
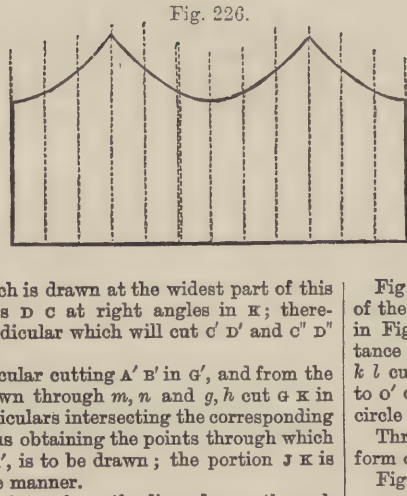


Fig. 226.



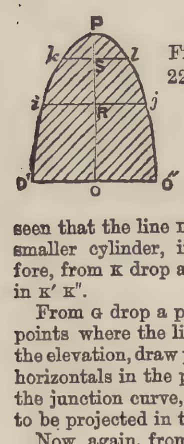


Fig. 222.

seen that the line L K, which is drawn at the widest part of this smaller cylinder, intersects D C at right angles in K; therefore, from K drop a perpendicular which will cut C′ D′ and C″ D″ in K′ K″.

From G drop a perpendicular cutting A′ B′ in G′, and from the points where the lines drawn through *m*, *n* and *g*, *h* cut G K in the elevation, draw perpendiculars intersecting the corresponding horizontals in the plan, thus obtaining the points through which the junction curve, K″ G′ K′, is to be drawn; the portion J K is to be projected in the same manner.

Now, again, from the points where the lines drawn through *m n*, etc., in the elevation cut G K and J K, draw lines parallel to L K, cutting H I in several points, left unlettered to test the knowledge of the student. From these points perpendiculars are to be drawn intersecting the horizontals in the plan, which

Fig. 222.—Draw the horizontal O′ O″ equal to the diameter of the cylinder. At O draw a perpendicular to P, equal to O P, in Fig. 220, and set off on it the lengths R and S—the distance of the points at which the lines drawn through *i j* and *k l* cut O P—viz., R, S. Draw lines through R and S parallel to O′ O″ (Fig. 222), and make them equal to *i j* and *k l* in the circle *o* (Fig. 220).

Through O, *i*, *k*, P, *l*, *j*, O″ draw the half ellipse, which is the form of the section at O P in the elevation.

Fig. 223 is the section at N O, and Fig. 224 is the section at G K and J K.

Fig. 225.—In order to develop the surface of this cylinder, draw a horizontal line, as X X, and a perpendicular, as M′ B′.

Now returning to the elevation, produce the line B E, and draw M A at right angles to it.

It will be seen that this addition completes the lower end of the cylinder, as if that portion were embedded in the ground-plane; thus the real length of the cylinder is proved to be the distance between M and B, and it will be clear that if the cylinder stood on M A, the height of each point in the section would be the length of the perpendiculars drawn from them; but they would be further apart than they appear to be on the elevation, in which they seem to become closer as they recede from the centre line.

Therefore, from M′ (Fig. 225) set off the divisions *k*, *i*, *d′*, *g*, *m*, *e*, and *l*, *j*, *d″*, *h*, *n*, *e*, measured from the section in Fig. 220.

From each of these points erect perpendiculars. If the circle be large it is advisable to divide again, so as to obtain more perpendiculars, as shown on the left side of the figure, since by this means the difference between the arcs and the straight lines represented by the divisions is diminished.

Now from M′, in Fig. 225, mark off the length M B, taken from Fig. 220, and on each of the perpendiculars mark off the lengths of the lines correspondingly lettered in Fig. 220—viz., measuring from A M in Fig. 220, and setting off the distances from the line X X in Fig. 225. Now through *e*, *m*, *g*, *d*, *i*, *k*, B′, *l*, *j*, *d*, *h*, *n*, *e*, draw the curve for the top of the cylinder.

From each of these points set off the *uniform* length, B E, all the lines in the elevation parallel to B E being of the same length. The curve drawn through these points will be the form of the lower end of the cylinder.

It will be seen that the lines of penetration, N O and O P (Fig. 220), cut through the parallel lines through *i*, *j* and *k*, *l* in *r*, *s* and R, S.

Measure the distance of these points from A M, and set them off on the perpendiculars in Fig. 225, as already shown, and the curves formed in joining the points will be the shape of the aperture which would receive the cylinder on which the oblique one rests.

The opening G K J is obtained in the same manner, and is drawn half on each side, the metal or covering of the cylinder being supposed to be cut open on the line *e′* A.

Figs. 226 and 227 are the developments of the smaller cylinders, which, being obtained in the manner just explained, require no further comment.*

MECHANICAL DRAWING (*continued*).

THE TEETH OF WHEELS.

In order to transfer motion or force from one axis to another, wheels furnished with teeth are employed, and although the mathematical calculations connected with the forms, etc., of teeth do not come within the province of these lessons, the method by which those forms are to be drawn is a necessary and important part of our subject.

If two circular plates, A and B (Fig. 228) were placed so that their edges touched each other, and one of them were rotated on its axis, it would communicate motion by "rolling contact" to the other; but, of course, we could never expect very great force from such motion.

Now the transmission of force is one of the conditions of machinery; therefore such means are taken as shall enable the wheels, not only to communicate motion, but power as well.

One moment's reflection will convince the student, that if the edge of a penny be pressed against that of a farthing, whilst the latter is held between the finger and thumb, the farthing will only move round whilst it is being held very loosely, because the edges of both the discs are smooth. If, however, a half-crown and a sixpence be substituted for the former coins, the additional friction caused by the milled edges will allow of the sixpence being moved by the half-crown when held much more tightly than the farthing; in other words, the projections (or *teeth*) on the edges of the discs enable them to overcome greater resistance than if they were smooth.

It is clear, that although A (Fig. 228) would move B when their circumferences touched each other, yet if a weight attached to a cord were wrapped round the axle, as shown in the figure, resistance would be offered, and the edge of A would *slide* against that of B.

Let, however, a pin be inserted at C in A, and another at D in B, and it is easy to understand that as the one presses against the other during rotation, *motion* and *force* will be communicated.

But these pins could not pass each other, because the points of the circles on which they are situated would gradually approach until they absolutely touched each other, as at E. The motion would therefore be stopped altogether, or the pins would be broken off. It is therefore necessary that between the teeth spaces should be cut which shall sink into the edge of the disc, as shown at F and G. Then as the teeth approach each other, the point of the one enters into the space next to the other, and thus the action is continued. The motions, then, of wheels are exactly the same as those of two circles rolling upon each other.

The original circles which roll on each other are called the *pitch-circles*, and when the system consists of a wheel and rack (*a circle rolling on a straight line*), the line on which the circle rolls is called the *pitch-line*.

The great effort of the engineer in designing the teeth, is to enable the wheels to move with an accurately uniform motion: the various forms given, and the mode of constructing them, will form the subject of our study.

There are various kinds of wheels: the following are the most important:—

Spur-wheels are such as have their teeth standing out directly from the edge.

When the teeth are made of wood, and inserted separately

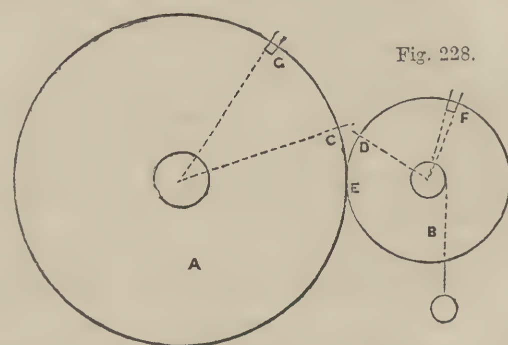


Fig. 228.

into the rim, they are termed *cogs*, and the wheel is called a *cog-wheel*—a form much used in mill-work. A sketch of this kind of wheel will be given in a future lesson.

Face-wheels have their cogs or pins placed perpendicularly to the face of the wheel.

Crown-wheels have their teeth standing perpendicular to the rim, as if the teeth had been first cut on a straight strip, which had afterwards been bent round.

Annular-wheels are such as have their teeth cut on the inside of the rim or ring.

Bevel-wheels are portions of cones—the teeth being cut on the slanting surface: they are, in fact, spur-wheels, the teeth of which are on the conical side, instead of the edge. They convey motion when the axes are at angles to each other. When the cones are equal, they are called *mitre-wheels*.

It is sometimes convenient that the axes of bevel-wheels should pass close to each other without intersecting; the teeth have then a peculiar form, and the wheels are called *skew-bevels*.

The curves generally used for the form of the teeth are the cycloid, the epicycloid, and the hypocycloid—the construction of which will be fully described in "Practical Geometry applied to Linear Drawing." It will, therefore, only be necessary here to remind the student that the cycloid is traced by any point in a circle whilst rolling along in a *straight line*; that the epicycloid is traced to a point in a circle rolling *against the edge of another circle*; and the hypocycloid is the curve traced by any point in a *circle rolling round the inner side of the circumference of another circle*.

The circle which forms the curve is called the *generating circle*. When the diameter of the generating circle is equal to the radius of the circle in which it rolls, the hypocycloid becomes a straight line; this will be referred to hereafter.

* For elementary instruction as to development of cylinders and their sections, the student is referred to lessons on "Projection."

OPTICAL INSTRUMENTS.—V.

BY SAMUEL HIGHLEY, F.G.S

SPECTACLES FOR THE PRESBYOPIC (*continued*).

THE following table, drawn up by Donders from carefully recorded statistics, may prove of service to the optician as a guide to what glasses are required at different ages in emmetropia, with normal acuteness of vision, and accommodation for writing and for reading ordinary type :—

a AGE.	GLASSES REQUIRED. *b* In Present. E.	GLASSES REQUIRED. *c* In Original. E.*	*d* Distance of Distinct Vision.	*e* R_2 Far Point.	*e* P_2 Near Point.
			Inches.	Inches.	Inches.
48	1-60th	1-60th	14	60	10
50	1-40th	1-40th	14	40	12
55	1-30th	1-28th	14	30	12
58	1-22nd	1-20th	13	22	12
60	1-18th	1-16th	13	18	12
62	1-14th	1-12th	13	14	12
65	1-13th	1-10th	12	13	11
70	1-10th	1-7·5th	10	10	10
75	1-9th	1-6·5th	9	9	9
78	1-8th	1-5·5th	8	8	8
80	1-7th	1-4·5th	7	7	7

We have said that presbyopia occurs not only in the emmetropic eye (Fig. 6, page 160), but also in the hypermetropic (Fig. 8), and in the myopic (Fig. 10), that is, if we adopt Donders' standard near-point at 8 inches.

Thus, if with the convex glass which neutralises the hypermetropia (that is, renders the hypermetropic eye capable of uniting parallel and divergent rays upon the retina), the near-point lies at 12 inches, the patient is not only hypermetropic, but also presbyopic, and he will require two different pairs of convex spectacles—one pair to enable him to see from 12 inches to infinity, and another stronger pair, which will bring his near-point nearer than 12 inches.

Or should the patient possess a myopia $= \frac{1}{16}$ (his far-point lying at 16 inches from the eye), and we find his near-point lies at 12 inches; then he is not only short-sighted, but long-sighted also. His myopia $= \frac{1}{16}$, his presbyopia (as shown above) $= \frac{1}{24}$.

The opinion of oculists is divided as to the proper time emmetropics should begin to use spectacles. On the one hand, it is asserted that the employment of convex glasses should be deferred as long as possible; and to this prejudice the vanity of human nature is too ready to give support, the adoption of spectacles being in such cases regarded as an outward visible sign of an inward material decay—of the advent of age. But must it not be regarded as folly to unnecessarily weary both eyes and brain, in guessing, with much trouble, at letters, stitches in needlework, etc., which could be seen distinctly by the aid of spectacles?

But, on the other hand, an opposite error of judgment prevails, viz., that, by recommending the early employment of weak spectacles, the power of vision may be preserved; hence such terms as "preservers," "conservative spectacles," in connection with which may be noted the introduction of "amber glasses," "tinted spectacles" (light yellow, pink, or blue glasses), *et hoc genus omne.* In connection with the latter, the following caution may be given—viz., that most persons are ready to employ them, on account of their agreeable, soothing influence; but we must remember that coloured, even but slightly-tinted glasses, withhold from the retina the ordinary stimulus of white light, so that its sensibility is abnormally increased, and thus they create a permanent necessity for their constant use. It need hardly be said that a more than normal sensibility in the retina is an inconvenience, which, moreover, predetermines to disease. The common sense of the question seems to be, that so long as the eye does not err, and remains free from fatigue in the work required of it, its own power is sufficient, and it is inexpedient to seek unnecessary assistance from convex glasses. On the contrary, as soon as the eye begins to feel teased by the every-day work required of it, the aid of the optician, or the advice of the oculist, should be sought.

Another question arises. After commencing the use of spectacles, how often ought the sights to be changed? The answer is: As slowly as possible; for every advance is, as it were, a milestone passed on the road to virtual blindness—that is to say, were the rate of change too rapid, and the person lived to an advanced age, a point might be arrived at when the optician's resources would be exhausted, and then the dimmed sight could no longer be aided, for the deepest lens would have been passed, and found to fail with increasing years.

The proper course is to use the weakest spectacles that will give the desired assistance, only in the evening, and to keep these for day spectacles so soon as stronger glasses are required for evening work; and so with every change, the weaker glasses being used for day, the new and stronger glasses for the evening. Moreover, the weaker glasses should be used for writing, while the stronger are reserved for reading; for the reason that the wearer can see with them at a greater distance, and to avoid the bent position for writing which becomes a custom with the short-sighted—a position injurious to the eyes, as it tends to throw the blood to the head, and so congest them.

And here it may be noted that should a person apply to his optician for an increase in the power of his glasses, at shorter intervals than is usual, and a rapid increase in his presbyopia is really observed, this may be suspected as a premonitory symptom of "glaucoma," especially if a greenish opacity behind the pupil is noticeable: in such case the person cannot be too quickly sent to the ophthalmic surgeon, for the threatened disease is of a formidable nature.

Contrary to what might be expected, persons who are occupied almost the whole day in reading, writing, or other close work—even such as that of watchmaking and engraving—who are obliged to employ a magnifier, or as microscopists, do not essentially injure their eyes, nor does their range of accommodation diminish scarcely, if at all, more rapidly than it does in sailors, agriculturists, and others, who, for the most part, look at distant objects. At least, this holds good with emmetropics, and even those disposed to myopia; though much reading or writing tends to make them more short-sighted, yet such occupations have no influence on their range of accommodation.

But there are morbid conditions which cause the range of accommodation, and sometimes also the amount of refraction, to diminish more rapidly than usual, such as general debility (the result of exhausting disease), premature old age, and glaucoma previously referred to. In all such cases, the optician should only supply spectacles under the guidance of the ophthalmic surgeon.

In many instances the optician will be called on to adapt glasses to meet the requirements of the calling of his customer. Some occupations, such as minute drawing, engraving, watchwork, minute anatomical dissections, and microscopical mounting, require the constant use of the magnifying glass. In other work the eye, even with normal acuteness of vision, must at least be still accommodated for distances from 4 to 6 inches. In such cases convex glasses become a necessity, to render permanent accommodation for such distances possible. In other cases, the work must be performed at definite distances, such as, in writing in large registers, reading in the pulpit or in the orchestra, in the use of certain musical instruments, etc. It is often desirable to bring the distance of distinct vision to 18 inches, or 2 feet; so weaker glasses are necessary where, in the former cases, stronger ones would be required than would be given for reading or writing. Guided by sound principles and practical experience, the optician soon finds what spectacles meet the special requirements of each case.

* This will be referred to under treatment of *Hypermetropia acquisita.*

THE STEAM-ENGINE.—V.

STEAM-PIPES—THE CYLINDER—PRINCIPLE OF ALTERNATE MOTION—THE PISTON AND ROD—PACKING OF THE PISTON.

HAVING now mastered the mysteries of the boiler and its various appendages, we must turn our attention to the mechanism and construction of the engine itself. This, as we have explained, may be, and often is, entirely separate from the boiler, yet without it the engine is of no use. The boiler may be regarded as the part of the machinery where the power is generated, and the

engine as that portion where this power is brought under control and made to accomplish the ends we desire.

In locomotives and portable engines the two are usually combined, the various parts of the engine being securely fastened to the boiler itself or the framework which supports it; but this is done merely as a matter of convenience. In large manufactories, where much machinery is employed, the boilers are almost universally separate, and often at a distance from the engines to which they supply steam; and this is the most general plan. There are usually several boilers placed close together, and they may be employed either singly or together; so that in case of any one requiring repair, steam may still be generated in the rest, and no stoppage of the machinery is caused.

Several engines are often driven from one set of boilers. In many cases, indeed, a small engine is attached to the machine it is to drive, and is made a part of it, and a small steam-pipe is then connected to it. This is often found to answer better than driving the machine from the ordinary shafting, and has, besides, another advantage—viz., that if flexible steam-piping be employed, the machine may easily be shifted from place to place without altering the connections. In the case of pumps, this is frequently found to be a very great convenience. Cranes, centrifugal drying machines, and various other small machines, are frequently thus fitted with an engine of their own.

It will, however, be much better to defer the consideration of these special engines for the present, and first of all to inquire carefully into the construction and action of the various parts of some simple form of engine; and, having done this, the various modifications introduced will then be far more easily understood.

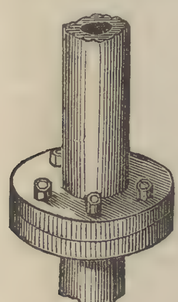


Fig. 21.

We will therefore inquire in this way into the principle of the most common form of engine, such as may frequently be seen in any large factory, and is known as a "low-pressure beam engine."

Various lines of shafting run along the different floors of the building, all of which are set in motion from the engine. All the various machines are then driven from this shafting, pulleys or sheaves being fixed at various intervals along it, over which straps pass to the different driving-pulleys of the machines.

In the boiler we have a continual production of steam at a high pressure, which will find its way into the air as soon as any escape is provided for it. The first thing, then, is to conduct this steam to the engine. For this purpose a pipe starts from inside the boiler, and passes through it and on to the engine. The mouth of this pipe is usually placed in the upper part of the steam-chest, or, failing this, as near the top of the boiler as possible, so as to guard against the fine spray, which is produced by the rapid ebullition, entering the pipe with the steam, and being deposited in it or in the various parts of the engine. Much care is required in arranging for this, as otherwise excessive condensation of water, technically called "priming," will be produced, causing much inconvenience and loss of power.

Wrought-iron piping is usually employed for the passage of the steam, and it should be of sufficient diameter not to impede the passage of the steam, since that would cause a material diminution in the pressure. This piping has to be very carefully made, and tested for strength. At the ends of each piece are flanges with bolt-holes drilled through them, and their faces are turned so as to be nearly true. When two pieces are to be joined together, some hemp packing, well smeared with red lead, is laid spirally on one face, the other is then brought up against it, bolts are passed through the holes, and the nuts are firmly screwed on (Fig. 21). The joint thus produced will last indefinitely, and if carefully made is perfectly steam-tight. Other kinds of packing are sometimes employed in place of hemp and red lead.

When the engine is at any distance from the boilers, and the steam has therefore to travel along many feet of piping, there is a considerable loss of heat by radiation from the pipe. To guard against this it is nearly always packed with straw, or covered with wood, felt, or some other non-conducting material. Very frequently this "lagging" brings up the size of the pipe to that of the face-plates, so that they are hidden, and the pipe appears to be of uniform size throughout. The steam-pipe usually leads direct to the cylinder, and it always has a valve in it near this point, by means of which the steam can be shut off when we wish to stop the engine. Besides this, there is a valve placed just where the pipe leaves the boiler, so as to shut off steam there in case of any injury to the first valve or the pipe; and in addition to these there is usually a "throttle-valve" in the pipe, which is moved by the governor balls, and serves to regulate the supply of steam in accordance with the requirements of the engine, as will be fully shown hereafter.

Fig. 22.

The amount of force existing in the steam will, by a moment's consideration, be seen to be very great indeed. As already explained, a cubic inch of water when converted into steam occupies at the pressure of the air very nearly a cubic foot—that is, it expands 1,700 times. In doing this, it has to overcome the pressure of the air, and therefore exerts a pressure equivalent to raising a weight of 15 pounds to a height of 1,700 inches. This will be more clearly seen if we imagine our cubic inch of water to be placed at the bottom of a tube of indefinite length, having a sectional area of exactly one inch, and to have above it a piston, fitting the tube air-tight, but supposed to be without weight, and to move without friction (Fig. 22). Now the air presses with a force of 15 pounds on a square inch, and as this is the area of our tube, we may regard the water as pressed upon by a single weight of 15 pounds. Now let the water be gradually converted into steam, the piston will rise till it attains an elevation of 1,700 inches, or 142 feet nearly, all the time resisting the pressure of the air, which is equivalent to lifting a weight of 15 pounds. This, then, is the work accomplished by the evaporation of one cubic inch of water—15 pounds raised 142 feet, or 142×15, that is 2,130 pounds raised one foot high. To remember this we may express it in the following statement, which can easily be borne in mind:—

The force produced by the evaporation of a cubic inch of water is sufficient to raise a weight of nearly one ton to a height of one foot.

Only a small portion of this force is utilised in any engine at present constructed; but we must now see how this portion is utilised in the ordinary forms. Various plans for driving machinery by means of this force have been suggested and tried: some have let the steam, as it issues from a jet, strike against a set of vanes, and thus impart motion to them; others have suggested the employment of a wheel similar in construction to that used in the water turbine; but the only plan that has come into use has been the employment of a cylinder with a piston moving up and down in it.

The cylinder consists of a strong cast-iron tube of large dimensions and of considerable thickness. Its size varies with the power of the engine; but it is usually about half as long again as its diameter. Its interior surface is bored or turned with great care, so as to be perfectly cylindrical and of uniform diameter throughout; it should also be free from flaws. Covers or caps are firmly bolted on to each end, the joints being packed so as to be perfectly steam-tight, and suitable apertures are made near the end to provide for the ingress and egress of the steam. As it has to withstand the pressure of the steam and the jarring of the piston, this cylinder must be firmly and strongly made.

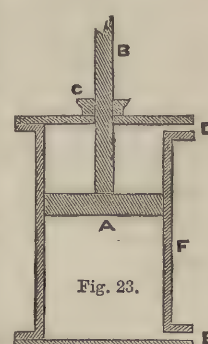


Fig. 23.

Inside this there is a piston which can move up or down, but fits steam-tight. It is likewise composed of metal, and is virtually a disc of considerable thickness firmly attached to the piston-rod, which moves through an opening provided for it in the upper cover. We can now understand, by reference to Fig. 23, the manner in which this piston is driven by the steam.

Let us first of all suppose that the piston is of considerable weight, and is nearly at the bottom of the cylinder, which

is so arranged that it cannot quite rest in contact with it. The steam from the steam-pipe is now allowed to enter the lower end of the cylinder, through the port E. Its pressure at once overcomes the weight of A and the pressure of the air on its upper surface, and raises it to the top of the cylinder, the air which previously occupied that space being driven out through D.

If now the steam be shut off, and the pipe removed, or, simpler still, if a second opening be provided, the weight of the piston will drive out the steam into the air, and force the piston down again to the bottom.

The steam may then be re-admitted, and the piston will be driven up again as before, and in this way an alternating movement of the piston-rod is obtained, which may easily be converted into one of rotation. This, then, is the simple principle of the engine, and, as will at once be seen, the chief difficulty here would be to provide some means for making the lower part of the cylinder communicate alternately with the steam-pipe and with the air. This may, however, be easily accomplished by means of a two-way cock, as shown in Figs. 24 and 25. In each figure C represents the pipe communicating with the lower part of the cylinder, and S the steam-pipe, while A is open to the air. The passage through the plug of the cock is curved, as seen in the section, and when in the position shown in Fig. 24, a direct path is opened for the steam to pass into the cylinder, while all communication with the air is cut off. When the piston reaches the top, the tap is turned one-fourth of a revolution, to the position shown in Fig. 25; the steam is thus cut off, and that already in the cylinder can escape through A into the air.

In this, which is the simplest form of engine, there are many important defects which have subsequently been to a greater or less extent overcome. The pressure of the air, it

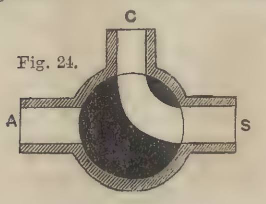


Fig. 24.

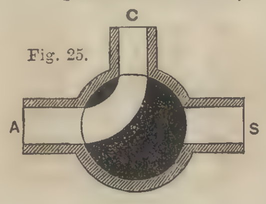


Fig. 25.

will be observed, obstructs materially the upward progress of the piston, since it presses on every square inch of its surface with a pressure of fifteen pounds. It does not, however, aid in driving it down, since when the piston is descending, both sides are equally exposed to its pressure. There is, therefore, in this way a very great loss of power. This is almost entirely avoided when a condenser is used. The steam then, instead of issuing into the air, is allowed to pass into an exhausted vessel, in which it is condensed into water, and a vacuum thereby produced. The pressure of the air then impedes the ascent of the piston as much as before; but, since there is a vacuum in the lower end of the cylinder, it aids the descent in almost the same degree, and thus, on the whole, there is little loss.

Another disadvantage of this form of engine is, that its action is very uneven. The piston is driven by the force of the steam to the upper end of the cylinder, while the return is accomplished merely by its own weight, or any weight with which it may be loaded. In some cases, however, this is not nearly so great a drawback as in others.

In a pumping-engine, for example, the whole strain is when the pump-rods are being raised, their own weight being sufficient to carry them down again. A single-acting engine is, therefore, employed for this purpose; the piston is, however, usually forced from the top to the bottom of the cylinder, the pump-rods being attached to the other end of the beam, so that the water is raised while the piston is descending. In a future paper we shall introduce an illustration of this engine, and enter into the details of its construction.

If we return now to our original cylinder (Fig. 23), we shall easily see that, if by any means we cause the steam to enter alternately at the upper and lower ports—the other port, in either case, being in communication with the air—we can make a double-acting engine, the piston being now driven in each direction, instead of in one only as in the former case. By using a four-way cock this may easily be done, and we shall thus have a model showing the principle of the double-acting engine. The student will from this understand the principle on which the steam-engine acts, and we can therefore turn our attention now to the construction of the piston and piston-rod, and the manner in which the supply of the steam to either end of the cylinder is regulated.

The piston is usually made either of cast-iron or brass, the latter being preferred, as it is lighter and does not so easily break. Round the edge of the disc a deep groove was formerly turned, which was completely filled with well-lubricated packing. The piston was then made in pieces, and the top disc attached to the rest by screws. By tightening these the packing was compressed and forced against the sides of the cylinder, so that the steam could not pass; at the same time the undue wear of the piston or cylinder was prevented. Fig. 26 will explain this mode of construction.

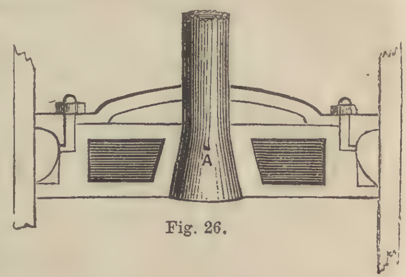


Fig. 26.

In practice, however, it is found that pistons packed in this way are far from durable, and much inconvenience is often caused by their getting out of order. They have, therefore, almost entirely given place to those which maintain steam-tight contact without packing, and are known as metallic pistons. In these there is a very great variety in the mode of construction, though the principle on which they all act is essentially the same.

The groove round the piston, instead of being curved, is rectangular in section, and contains, in place of the hemp, two or more packing rings, which are usually made of brass. These are flat rings, having the same external diameter as the piston; they are made in several segments, the ends sometimes being tongued and grooved to keep them in position. The joints in each ring are so arranged as to be intermediate to those in the others. Strong steel springs are then placed in the piston, in such a way as constantly to force the segments of these discs outwards, and the result is that they press against the interior of the cylinder, and become gradually worn, so as exactly to fit it, and as the pressure is uniform and the surfaces well lubricated, there is not much wear or friction. In Fig. 27 we have a cross-section of a piston of this kind. There are two packing rings, each of which is divided into two segments, as shown. Inside these is a thin steel ring, and then come the springs, of which there are five. These are made of strong steel, and may be tightened by the screws, which are seen behind them.

Pistons packed in this manner are found to last a long time without showing signs of wear, and may usually be easily repaired. The points required in any form of packing are perfect contact at all parts, so that no steam may pass by, and, on the other hand, not so strong a pressure against the sides as needlessly to increase the friction; and this medium may easily be obtained by properly adjusting the screws.

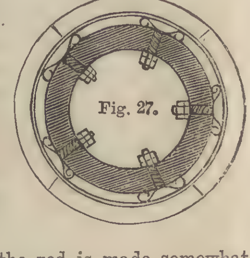


Fig. 27.

The piston-rod is frequently made with a flat disc firmly welded to its end. The piston then has a hole drilled through it to admit the rod, and its base is countersunk, to make room for the disc. When it is slipped on the rod, and is in its place, a pin is put through the piston edgeways, and holds both firmly together.

In other forms the lower end of the rod is made somewhat larger and tapering, so that when in its place it fits firmly, and, as in the former case, is kept from slipping by a pin driven through both, as shown at A in Fig. 26.

In locomotive pistons, and other cases, where the diameter is comparatively small, the piston and its rod are not unfrequently made in one piece, and all fear of their becoming loosened by the alternating pressure is thus avoided.

OPTICAL INSTRUMENTS.—VI.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLES FOR THE MYOPIC.

In selecting spectacles for the myopic, great care is necessary, as, on account of the morbidly distended condition of the eyeball, and of the tendency to get worse, unsuitable glasses might prove very dangerous. In some cases the myopia is so slight, that persons are not aware (as previously stated) that they are really short-sighted. On directing them to look at the distance-test, a decided improvement in their sight is admitted, on their trying slight concave glasses of 60 or 50 inches focus.

The detection of myopia, as a rule, is not difficult. It might be confounded with that weakness of sight termed amblyopia, for amblyopic persons, in order to obtain larger retinal images, hold small objects very near to the eye. How can we distinguish whether the patient is myopic or amblyopic? If he cannot (like short-sighted persons) distinguish very small objects, or if concave glasses, through diminishing the size of the retinal image too much, impair rather than improve his sight; and, further, if he can see test type No. II. at five inches' distance, and can see type double that size at twice that distance; then

number sixteen of Jäger

Trent

he is *amblyopic*; for in this case the retinal images increase in proportion to the size of the print, and all the weak-sighted require is large retinal images; whereas in myopia it is different, for although the short-sighted see large type further than small, the proportion between the distance and size of the print is far less. If, with a suitable concave lens, a person complaining of short-sightedness can read type of the size shown in the words "number eighteen" in this page, and the words "number sixteen of Jäger," at the same distance as the normal eye—viz., 20 feet—then he is simply *myopic*. If, however, with the most carefully selected glasses he can only read the word "Trent" in this page at the distance of 20 feet, then it is a case of *myopia complicated with amblyopia*, and the less the concave glasses correct, the greater is the degree of co-existing amblyopia, and *vice versâ*.

number eighteen

We must be careful not to jump to the conclusion, that because a person cannot see well at a distance, he must of necessity be myopic; for he may be hypermetropic, in which case convex, and not concave lenses will be required to render distant objects clearly discernible.

In extreme cases of myopia, due to lengthening of the eyeball, *sclerotico-choroiditis posterior* is almost always present, and, according to Von Groefe, if the far-point lies nearer than 5 inches from the eye (the myopia being greater than $\frac{1}{5}$), then *sclerotico-choroiditis posterior* is present, and this dangerous complication requires medical treatment.

In determining the range of accommodation in the myopic eye by Von Groefe's optometer, as previously described, we found in the case stated that the amount of

$$A = \frac{1}{3} - \frac{1}{5}$$

Now, what glasses would be required to enable the patient to see distant objects? By the 6-inch convex of the optometer we have changed his eye into a very myopic one—in fact, into a myopia of $\frac{1}{5}$; for we should have to place a concave of 5 inches focus before the convex of 6 inches focus to enable it to see a distant object, for this concave lens would render parallel rays as divergent as if they came from 5 inches distance. In order to find the proper concave glass for distance, we deduct concave 5 from convex 6—

$$\frac{1}{6} - \frac{1}{5} = \frac{1}{30}.$$

Hence the suitable concave glass will be No. 30.

We have thus theoretically found the proper glass; but, on account of the convergence of the optic axes preventing the eyes from accommodating themselves for the far-point (only attainable when we look at distant objects with parallel optic axes), we should probably find in practice that this would prove too strong; for it is a rule that we should give the weakest concave spectacles with which the patient can see clearly and distinctly at a distance, so that he may only make use of a minimum of his power of accommodation, and not have to strain it unduly when observing near objects; for we must remember that he will but seldom have to look for any length of time at a distance, but at near and distant objects alternately. We therefore let him look at the distance-test at 20 ft. distance, and find that he can distinguish it perfectly. We now alternately place very weak concave and convex glasses before the spectacles, and note their effect. If the convex improves his vision, the spectacles theoretically selected are too strong, and we must give glasses of lower number. Should the concave improve vision, the selected glasses are too weak. But if neither convex nor concave effect any improvement, the spectacles that theory indicated suit exactly.

By thus assisting myopes in seeing distant objects we change their eyes into normal ones, for we enable them to bring parallel rays to a focus upon the retina (see D, Fig. 2, page 111). We can also advantageously assist the myopic in seeing things at a short distance, such as reading a sermon, lecture, music, etc., at a few feet distance: as, for instance, a person wishing to see music, while playing on a musical instrument, say at 2 feet distance. Say, for objects at an infinite distance he is using concave spectacles of 12 inches focus. As his myopia equals about $\frac{1}{12}$, then—

$$-\frac{1}{12}+\frac{1}{24}=-\frac{1}{24}.$$

Hence concave 24 will enable him to read music at 2 feet distance. It is, however, a much debated question whether short-sighted persons should be allowed to wear spectacles for reading, writing, etc.; but Donders, one of the greatest authorities on the treatment of defective vision by means of spectacles, considers on physiological and pathological grounds that their use is advisable, except under circumstances presently to be named—that their employment is to be strongly recommended. In the first instance it is advisable to give the patient weaker glasses for reading than for distant objects; but if his accommodation be good, it is better, at a later period, to give him spectacles that will completely neutralise his myopia. In the same way, as in the previous case, we have to determine what glasses will meet the requirements of a short-sighted person who wishes to read at a distance of 12 inches. If his myopia $= \frac{1}{6}$, then—

$$-\frac{1}{6}+\frac{1}{12}=-\frac{1}{12};$$

and we give him No. 12 concaves. For the reason previously given, somewhat weaker glasses are desirable.

We should warn such patients against bringing a book close to the eyes, on feeling fatigued from reading. Instead of putting it down, they bring it nearer to the eyes, in order to obtain greater retinal images, and thus strain and tax their power of accommodation too much; and if this is made a practice, it will increase their short-sightedness. Again, the same person should be supplied with weaker glasses for writing, if there be a tendency to congestion of the head, so that the injurious results of a stooping position may be avoided.

When a myopic person complains of fatigue, and that after reading without glasses for a short time the letters become confused, blurred, and appear to run into one another, with pain in and around the orbit (*Asthenopia*—see Diplopia, page 160), then the use of suitable concaves for near objects is indicated. This kind of weakness of sight is especially felt after reading, writing, etc., in a gloomy place or by artificial light; and to ease the fatigue, the person so affected involuntarily rubs his hands over his forehead and eyelids. After a few minutes' rest he once more sees distinctly, but the same annoyance again occurs, only more rapidly than before. The longer the rest given, the longer can work be continued. As a rule, however, it will (according to the experience of Donders) be found that hypermetropia is at the bottom of this affection, and then convex (not concave) lenses must be employed in the ultimate cure. Asthenopia proceeds from fatigue of the muscular system of accommodation.

Myopes should further be warned against anything that tends to produce strong convergence, or writing, or making rectilinear drawings on a horizontal surface, to which end a high and greatly inclined desk should be used; and they should be advised to read with the book in the hand. Emmetropic and hypermetropic do not suffer injury as quickly as myopic eyes from the use of unsuitable glasses. It is better to use glasses that are rather too weak, or no glasses, than such as are too strong, for strong glasses make hypermetropic eyes myopic, and myopic eyes hypermetropic. As a rule, it is much less injurious to produce a certain degree of myopia than of hypermetropia, as in the latter case much is required of the accommodative power: so in myopia we must beware of glasses that are too strong; in hypermetropia, those that are too weak. But we must recollect that every rule has its exceptions, and all the circumstances connected with each particular case, which can exercise an influence on the choice of spectacles, must be duly considered.

Myopia is most prevalent in civilised countries, and, as a rule, in their most cultivated ranks; and while, on the one hand, it is often hereditary, on the other, its foundation is too often laid in schools—more particularly boarding-schools, where by bad lights the pupils read bad print in the evening, or write with pale ink—and so developed in early life. The causes which give rise to myopia are still more favourable to its further development. A near-sighted eye is not a sound eye; its defect is not dependent upon a simple anomaly of refraction, but upon anatomical and pathological causes, which may be progressive in character, and so constitute a true disease of the eye. The higher the degree of the myopia, the less is it likely to remain stationary. In youth almost every myopia is progressive, and is then often accompanied with symptoms of irritation. This is the critical period of the myopic eye. If the myopia does not increase too much, it may become *stationary*, and may even decrease in advanced age; if developed in a high degree, it is subsequently difficult to set bounds to it—it may become *temporarily progressive* or *permanently progressive*. Every progressive myopia is threatening with respect to the future; so that by the age of fifty or sixty, if not much earlier, the power of vision may irrevocably be lost, either through separation of the retina from the choroid, from effusion of blood, or from atrophy and degeneration of the yellow spot. On the advent of myopia in youth, all promoting causes should be carefully avoided, and its rate of progress carefully watched by the oculist.

SPECTACLES FOR THE HYPERMETROPIC.

In myopia, through the state of refraction being too great, or the optic axis being too long (see Fig. 10, page 160), parallel rays are brought to a focus *before* the retina when the eye is in a state of rest; in hypermetropia we have just the reverse of this (see Fig. 8, page 160), and through the refractive power being too low, parallel rays are brought to a focus *behind* the retina, which defect we correct by means of a concave lens suited to the degree of hypermetropia, so as to give the slightly divergent, almost parallel rays, emanating from distant objects, a convergent direction, and bring them to a focus *on* the retina.

In some cases stronger spectacles may be required for near objects also. We need not feel surprise that hypermetropics are often not aware that they see distant objects worse than other people, whereas they would soon discover any deficiency of sight that would affect their capacity in reading and writing. A hypermetropic patient usually complains that after he has been reading or writing for some time the letters become ill-defined, and appear to run into each other, while at a distance, he says, he can see perfectly. The other usual indications of this defect have been previously given. All hypermetropics with a fair amount of accommodation habitually expend a portion of this, to compensate more or less for the deficient refractive power of the eye. The function of accommodation, which by normal eyes is only employed for near objects, is thus by hypermetropic eyes partially, or even nearly exclusively, used for distant ones, which accounts for such persons frequently being unaware of this defect, as previously stated. The proper corrective convex glass can only be found by trial on the distance-test.

We may thus determine the *manifest*, and then by degrees ascertain and correct the *latent* hypermetropia; but as the most efficient method of determining this is by completely paralysing the power of voluntary accommodation by the application of a strong solution of atropine, it is palpable that this defect, when once diagnosed, must pass out of the hands of the optician into those of the ophthalmic surgeon. The patient's power of neutralising his hypermetropia being thus destroyed, his vision will be found to be materially deteriorated, but may again be restored by a convex glass of higher power than that required previous to the paralysis of accommodation.

SPECTACLES FOR EYES OF DIFFERENT FOCI.

As a rule, there is, in all respects, great symmetry between the right and the left eye; but occasionally there is to be found a great difference between the refractive power of the two eyes. We should, therefore, always test each eye separately as to its acuteness of vision, range of accommodation, and state of refraction. All imaginable combinations of refraction occur: with emmetropia in one eye there may be myopia or hypermetropia in the other; hypermetropia or myopia may occur in very different degrees in the two eyes; or the one eye may be myopic, the other hypermetropic. When astigmatism occurs in one eye only, as a rule it will be found that in other respects harmony of refraction exists on both sides; that is, with hypermetropia on one side, the astigmatism in the other will be hypermetropic; with myopia in the right, there will be myopic astigmatism in the left; with emmetropia, the astigmatism is mixed. With difference of refraction we may find binocular vision—vision with each of the eyes alternately—or constant exclusion of the one eye.

When binocular vision is present, at any distance, our aim must be to maintain this, and, if possible, to extend it over a

greater region. In the choice of glasses, where a difference of refraction between the two eyes exists, we allow the eye with least acute vision to remain subordinate to the stronger one, for which we supply the weaker glass, should it be advisable to give lenses of different foci.

It is a popular belief that when two eyes differ, as a matter of course glasses of different foci must be necessary; but in practice this by no means follows, for it is only when extreme difference between the refractive power of two eyes exists that such a course is advisable. When there is only a moderate amount of difference between the refractive power of two eyes, we may give similar glasses for both eyes; and as the relation between the two eyes, to which the person has grown accustomed, remains unchanged, he is satisfied. If we adopted the opposite course, though we make the range of accommodation for both eyes more equal, the magnitude of the images in each would be different, and the result unsatisfactory.

With hypermetropes, when there is imperfect acuteness of vision, it may be advantageous to produce, by means of glasses of different foci, nearly accurate images on the two retinas, by whose co-operation the power of distinguishing is thus, in many instances, really increased.

In rare cases, when the difference between the two eyes is great, and binocular vision is absent, the person may believe himself blind in one eye, especially if that eye be so very short-sighted that objects must be brought unnaturally near to it before they can be recognised—so close, indeed, that the fact of its *not* being deficient in vision may only be discovered when accidentally some object has been brought close to that eye. In such cases, while one eye may require a lens of 20 inches focus, the other may only be suited with a concave of 2 inches. The most suitable glasses must be determined by careful trial.

ASTIGMATISM.

In astigmatism the refractive power of the eye differs in different meridians of the cornea. It is a defect that is not remediable by the ordinary spherical lenses, but by segments of cylinders, which refract only transversely to their axes. This defect is usually tested for by means of lines ruled at different inclinations to each other, such as are given in Snellen's test types, and noting which of such lines are recognised simultaneously; or by the binocular method of M. Javal, whose test-plates consist of two similar circles, one being divided by radii corresponding to the hours on a watch-face, with intermediate shorter radii corresponding to the half-hours; the other being marked with the hour numbers corresponding to the longer radii of its fellow. These are placed so that their centres correspond to the distance between the pupils of the eyes, and are viewed through two lenses, say of 3 inches foci. This test-plate is withdrawn gradually, till all the lines become dim and disappear, excepting one in each disc. Then, beginning with the lowest power, a set of *cylindrical concaves* are brought before the eyes one after the other, with their axes perpendicular to the radius that has remained discernible, till the glass is found which makes all the radii equally black. The meridian of astigmatism, together with the number and position of the correcting glass, is thus determined.

The circles cannot be discerned unless the visual lines are parallel and the head straight. The relative position of the visual lines being a fixed one, this sufficiently guards against any change of accommodation. The patient may state what line he really sees by aid of the hour numbers, as these are not seen by the same eye that notes the radii. This also affords a constant test of binocular vision.

Astigmatism may also be tested by Stokes's "astigmatic lens." This consists of two cylindrical lenses, the one plano-convex l of $\frac{1}{10}$; the other plano-concave $l' - \frac{1}{10}$. The first is fastened into a broad metal ring, the second into a ring that works within the other, to allow of these lenses rotating axially past each other, with their plane surfaces face to face. The outer ring is graduated, and an index-point is engraved on the edge of the inner ring. When the index points to zero or 180°, the axes of the two cylindrical lenses are parallel, and the combination equals a concavo-convex cylindrical lens, with equal radius of curvature of the two planes, whose action is about $= 0$. If the index points to 90° or 270°, the axes of the cylindrical lenses stand perpendicular to one another, and the system has its maximum of astigmatic action, so that by rotating from 0 to 90° the astigmatism ascends from 0 to $\frac{1}{5}$. To save calculation, different degrees of astigmatism are given directly upon the engraved scale. The instrument is set to the degree of astigmatism suspected in the patient, and it is then rotated before the eye while it is fixed upon the distance-test. If improvement be observed in a particular position, the action of the instrument may be increased or diminished until the maximum of distinctness is obtained. The absolute correction of astigmatism indicated by this instrument requires great care, and pertains to the domain of the ophthalmic surgeon rather than to that of the optician, who, however, must carry out the optical remedy the surgeon prescribes for the determined degree of astigmatism.

BUILDING CONSTRUCTION.—XII.

JOINTS IN TIMBER (*continued*).

ANOTHER excellent method of joining beams of timber is that often adopted by ship-carpenters, called "fishing" the beam; and this is used, not only in original construction, but constantly in repairs.

This system consists in placing the two beams end to end, and clasping them between two similar pieces, then either bolting or strapping all three together. In Fig. 91 both these methods are shown. If strapping be adopted, it will be necessary to *scarf* the side pieces to the middle pieces, to prevent any chance of the middle pieces being drawn out. Scarfing timber will be presently spoken of.

This system was used by M. Perronet for the tiebeams, or stretchers, by which he connected the opposite feet of a centre on which an arch was being built, and which, giving way under the load, had pushed aside one of the piers above four inches. Six of such beams not only withstood a strain of 1,800 tons, but by wedging behind them, he brought the feet of the truss $2\frac{1}{2}$ inches nearer together.

These stretchers were 14 inches by 11, of sound oak, and could have withstood three times that strain. M. Perronet, however, fearing that the great length of the bolts employed to connect the beams of these stretchers would expose them to the risk of bending, scarfed the two side pieces into the middle piece. The scarfing was of the triangular kind, called "Trait de Jupiter" (which will be described in connection with Fig. 98), each "jag" being only 1 inch deep, whilst the faces were 2 feet long, and the bolts passed through close to the angles.

Of course, the methods here described are open to the objection that they increase the width of the beam at the juncture, and that they have a clumsy appearance. This must be admitted; but it is equally certain that they are the strongest systems, and should in every case be used where absolute stability is of more importance than the appearance.

The method of joining next in simplicity is that called "scarfing," which may be of the rectangular or oblique kind. The former is shown in Fig. 92. It consists in "halving" the pieces on to each other, and bolting them together.

Now it will be clear that, when bolted together, the wood will only be *half* as strong as it was before being cut, as half its thickness has been cut away, and therefore the widths $a\ b$ and $c\ d$ represent all the strength remaining in the beam; and even this is injured by the bolt-holes, as already referred to. This is in some degree remedied by affixing iron plates at A and B. But although the beam thus formed might be available for columns, or other vertical purposes, it will be seen that if exposed to cross strain it is liable to give way; for the iron plates, being of but small section, are liable to bend under the weight, whilst the bolts, too, might bend or tear out; and against any forces which might tend to draw the pieces apart no greater resistance is offered.

The author therefore proposes—1. That the parts which are to be halved together should be left several inches longer than required for the mere joint, the surplus portion of each to be formed into a dovetail, to be sunk into the thick part of the other, as at A (Fig. 93). If this is done at both ends, a great protection against the parts being drawn asunder is provided.

2. That instead of bolts, coupling-boxes be employed at each end to cover the joints, as at B. These boxes to consist of a bottom and sides, the latter having flanges to which the top is bolted. This will give perfect strength to that which was previously the weakest part. Two or three bands around the

middle part will complete the joining, and these may be slightly countersunk into the *sides* of beams, by which means the parts will be still more surely prevented sliding over each other, whilst they will not be materially injured by the small quantity of wood taken away in that part.

By this system the size of the beam is only increased by the mere thickness of the iron-work, which may be easily covered by a cornice or other joiner's work, should the situation require it.

Fig. 94 is an example of the oblique system of scarfing, and here again it will be seen that, if considered as two pieces of wood joined, it has as a tie but half the strength of an entire piece, supposing that the bolts, which are the only connections, are fast in their holes. The ends of this scarf require strengthening by plates, and a bolt is required through the middle of the

Fig. 96 differs from Fig. 95 only in having three keys. The principle and longitudinal strength are the same. The long scarf of Fig. 96 tightened by three keys enables it to resist a bending much better.

None of these scarfed tie-beams can have more than one-third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third it will have less than one-third of the fibres to pull by.

Fig. 98 is the elevation, and Fig. 99 the plan of the French scarf before alluded to, called "Trait de Jupiter," which differs from the method shown in Fig. 97 only in the key being placed at right angles to the slanting line of the scarf, instead of parallel to the line of the beam, as in Fig. 97. The advantage of this method is supposed to be that, when the key in Fig. 97

Fig. 100.

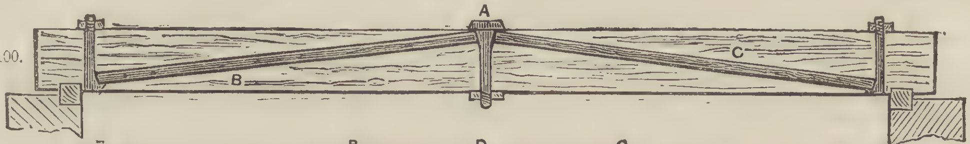


Fig. 101.

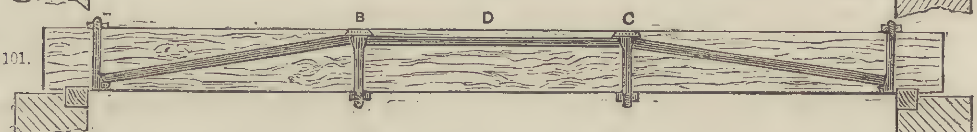


Fig. 103.

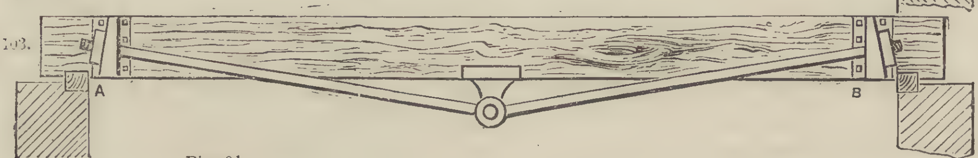


Fig. 91.

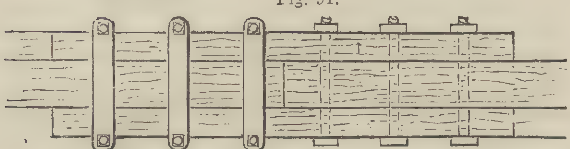


Fig. 92.

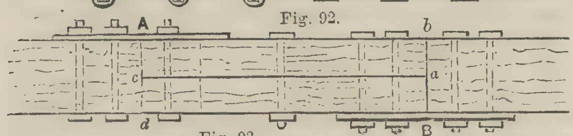


Fig. 93.

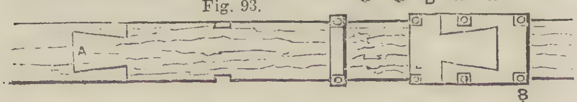


Fig. 94.

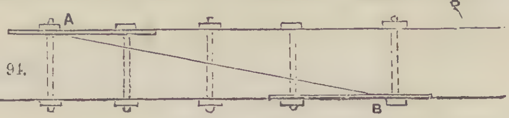


Fig. 95.

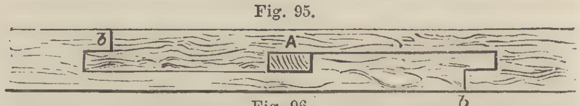


Fig. 96.

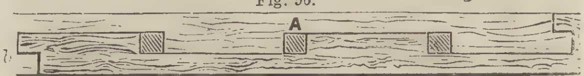


Fig. 97.

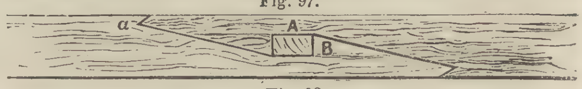


Fig. 98.

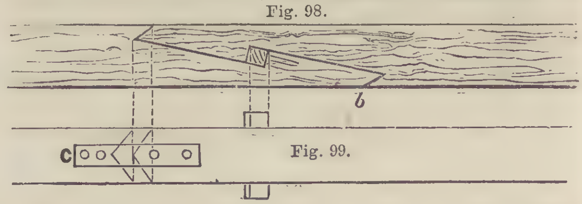


Fig. 99.

scarf. This form of scarf is not adapted for the office of a pillar, because the pieces, by sliding on each other, are apt to splinter off the tongue which confines their ends at A and B.

Figs. 95, 96, 97, and 98 exhibit forms of scarfing which are very generally approved, for either ties or posts. The keys represented at A in each are not absolutely necessary, for the pieces might simply meet square at those points. This form without the key needs no bolts, though they strengthen it to some extent, due allowance being made for the division of the fibres before alluded to; but if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction.

But the key is a great and ingenious improvement, and will force the parts together with perfect tightness; care being taken not to produce constant internal strain on the parts by overdriving the key. The forms of Figs. 95 and 96 are by far the best, because the tongue of Fig. 97 (*a*) is so much more easily splintered off by the strain or by the key than the square wood at *b* in the other two figures.

is driven in, it is liable to split off the piece B, as the force acts in the direction of the fibre; whilst in Fig. 98 the pressure of the key tends rather to press the fibres together than to separate them. But, on the other hand, it seems evident that as the object of the key is to push the parts *away* from the centre, so as to force them tightly against the tongue *b*, the stress coming in the slanting direction, shown at *b*, is by far more likely to splinter the tongue off than when coming in the parallel direction shown at *a* in Fig. 97. Both the French and the English methods are sometimes worked with several keys, and in both the ends of the beams are generally cut to a sally, as shown in the plan (Fig. 99), which prevents the beam bending in a side direction; and this may be further strengthened by the addition of an iron plate, shown at C.

When girders are extended beyond a certain length, they are liable to bend under their own weight. They thus require support, which it is not always possible to give by means of columns or posts. It therefore becomes necessary that the strengthening should be independent of any other support than

that which can be connected to, or contained by, the girder itself. This method is called "trussing." On this subject the writer takes the authority of Mr. Peter Nicholson, who says, "An excellent method to prevent the sagging (or drooping) without the assistance of uprights from the ground or floor below, is to make the beam in two equal lengths, and *insert* a truss, so that when the two pieces are bolted together the truss may be included between them, they forming its tie."

To prevent any bad effects from shrinking, the truss-posts are generally constructed of iron, screwed and nutted at the ends; and to give a firmer abutment the braces are let in with grooves into the sides of each flitch. The abutments at the ends are also made of iron, and either screwed and nutted at each of the ends, and bolted through the thickness of both pieces, with a broad part in the middle that the braces may abut upon the whole dimensions of their section; or the abutments are made in the form of an inverted wedge at the bottom, and rise cylindrically to the top, where they are screwed and nutted. These modes may either be constructed with one king-bolt in the middle (Fig. 100, A), or with a truss-bolt at one-third of the length from each end (Fig. 101, B and C). When there are two such bolts, they include a straining-place, D, in the middle.

It is obvious that the higher the girder the less will the parts be affected by the stress, and consequently there will be the less risk of their giving way under heavy weights, or through long bearings.

Mr. Nicholson says that the rods inserted may be "either of oak, or of cast or wrought iron. The latter material is, however, very seldom used." As this statement does not, however, give any reasons for the employment of either wrought or cast iron, a few observations on this subject are deemed necessary, especially as the immense improvements in the manufacture of iron have caused it to be so much more generally used than formerly, especially as the beams just described are almost entirely superseded by rolled or cast-iron girders.

It is necessary to the present purpose to state, however briefly, that cast iron is *crystalline* in its structure (that is, it is formed of separate particles which have settled into their position whilst the molten metal was cooling); whilst wrought iron is *fibrous* (that is, the particles have been, whilst in a soft condition caused by heat, hammered or rolled together, so that they are of a *long* instead of a *crystalline* form, and their adhesion is thus increased). Malleable iron is therefore able to bear longitudinal strain (that is, the force which would tend to pull the ends apart) better than cast iron; whilst the latter is best adapted to bear vertical pressure, as in a column, without bending or giving way. In brief, cast iron bears *compression*, and malleable iron *tension*; and, to speak familiarly, if the student wishes to know under what circumstances cast or wrought iron ought to be employed, let him ask the question, "Could a *rope* be used?" Now if any weight had to be supported from *below*, it is clear that a rope could *not* be used, and hence columns to bear a roof would be made of cast iron; but when the two feet, A, B (Fig. 102), of the iron rafters of a railway station have to be *tied* together, so as to prevent their spreading out, a rope would (though, of course, not permanently) answer the purpose, and therefore malleable iron would be best adapted. For it is clear that the weight of the roof would have the tendency to push the ends A and B outward, and that, if cast iron were employed, it would be in a state of tension which it is not calculated to bear; wrought iron is therefore best calculated to resist this strain. The rafters C and D, meeting in E, butt against each other, and as the weight of the roof is acting as *pressure*, the rafters are under a transverse stress as well as under a thrust, and here, too, iron would be used. From the shoe in which they meet, and which acts as the keystone of an arch, a rod (E F) can be suspended to bear up the tie-rod A B. Here, again, a *rope* would do; so that this rod must be of malleable iron. The point F being thus firmly held up, may be used as an abutment for "struts," F H and F G, and as these would have to bear the *pressure* of the roof, cast iron would be used; whilst from G and H rods of wrought iron might again be employed to draw up the tie-rod at I and J.

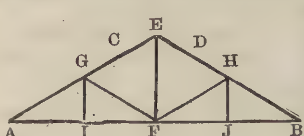


Fig. 102.

Returning now to Fig. 100, it will be evident that the pressure of the beam will be at A, and that the weight at that point would have the tendency to press *downward*. The trusses B and C therefore act as an arch, of which the king-bolt, A, acts as the keystone. The trusses B and C are therefore under *compression*, and cast iron or pieces of oak may be used.

The same remarks apply to the form of truss applied in Fig. 101, where it will be seen there is, as it were, an *arch* formed *within* the girder.

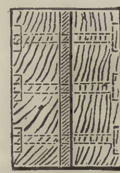


Fig. 104.

Where, however, it is not absolutely required that the trussing should be *within* the girder, far greater strength may be given by adopting the system the simplest form of which is given in Fig. 103. Here the weight of the beam is *suspended from its ends*, at which cast-iron shoes are placed, through which tension rods are bolted. These act on an iron support in the middle of the length, and as the nuts are screwed up at A and B, the tendency is evidently to raise the central casting, and so afford support to the beam. Girders of this form are used to support floors of upper rooms of warehouses, etc., or in schools where, for instance, the girls' department is over that for the boys; also in the now generally adopted system of scaffolding where travelling cranes traverse the work in progress. In such cases where the girders on which the trams are placed for the cranes are of great length, two supports, united by tension rods, are used.

Fig. 104 shows a section of a girder built up of wood and iron, and is called a *flitch* girder. An iron plate is inserted between the two planks, and iron bolts pass through all three; this is found convenient for the architraves of shop fronts, from the convenience with which the casing, cornice, etc., can be attached to it. Beams of this kind also are now almost wholly superseded by rolled or cast-iron girders.

CHEMISTRY APPLIED TO THE ARTS.—VIII.

BY GEORGE GLADSTONE, F.C.S.

SOAP-BOILING.

SOAP is a term applied to various compounds, but it is only with those included under its more familiar acceptation that it is proposed to deal in this article. Such soaps are formed by the action of soda or potash upon fats or oils. Both animal and vegetable oils will serve the purpose of the soap-boiler, though some of them possess peculiar properties which render them specially suitable for certain purposes.

It will be convenient to divide them into three classes—the hard, the soft, and the marine soaps.

The first of these includes a great variety, from the common yellow up to the fancy toilet soaps.

The alkali used in making hard soaps is soda, and it must be in its caustic state. If the hydrate of sodium, described in the previous article, be used, the alkali is already in the condition required; but if it be supplied in the form of the neutral carbonate, the soap-boiler has to make it caustic by digesting it with lime.

The fats or oils which may be used are very various. Tallow, olive, palm, and cocoa-nut oils are all extensively used. In addition to these natural oils, oleic acid deserves mention as a waste product of the candle manufactories, but which is of value to the soap-boiler. Rosin is also an important constituent of the yellow soaps. All these, with the exception of the last, which has an altogether different chemical composition, contain stearic or margaric acids, and the hardness of the soap produced is greatly dependent upon the proportion of these acids. The firmness of a soap is a matter of some importance, as one deficient in that respect is more wasteful.

Another important ingredient in soap, especially to the manufacturer, is water. As a mere matter of profit, of course, it is his object to make it take up as much as possible; but though a certain quantity be necessary, it is not wise to push the dilution too far, as the reputation of the maker would thereby suffer. A really firm and apparently good soap can be made, nearly three-fourths of which shall consist of water; but the consumer would very soon find out that its cleansing power was very small, and would not be likely to lay in a

second stock of it. The hard soaps generally contain from 15 to 30 per cent. of water.

The first step in the process of making soap is to boil the fat or oil with caustic lye in large caldrons. These are generally made of iron, and in the best establishments they are heated by steam, being at once more economical and more easily regulated. The steam-pipes are sometimes so arranged that the heat may either be applied externally, or that the steam itself may be forced through the contents of the caldron, in which latter case it not only fulfils its function of heating, but also stirs up the ingredients in a most effectual manner. The boiling-pans are generally made large enough to hold twenty-five to thirty tons of soap at a time.

The fat and alkali are thus boiled together until no grease is any longer seen floating on the surface, but the two have combined together and formed a milky kind of liquid of a neutral character, the acid of the fat having counterbalanced the alkali of the lye. According as the solution is acid or otherwise, more or less of the other ingredient is added, until the cauldron is nearly full, and the proper proportions have been nicely adjusted. Common salt is then thrown in, which readily combines with the water, but not with soap—as any one who has tried to wash in sea-water with common soap will know—the result being that the soap separates in curds, which float upon the surface of the saline liquid, the residue going by the name of *spent lyes*.

The spent lyes being drawn off, the saponaceous matter is again boiled up with fresh lye, and, if necessary, some more fat, taking care this time to have an excess of alkali in the solution. Salt is then again added to separate the soap from the liquid, after which the boiling is continued for some hours, in order to perfect the union of the soda with the fat. The soap is then ready to be skimmed off, and transferred to the frames in which it solidifies on cooling. It is then cut into bars and dried, and is ready for sale.

The frames are made with movable sides and a porous bottom, so that any lye which may be mixed with the curds shall drain away, and when solidified the frames are removed, and the block of soap is cut by wires, first horizontally into slabs, and then vertically into bars. In England the frames are all of uniform size, so that a block of soap measures exactly 15 inches wide, by 45 inches long, and 45 inches high.

The above description of the process will serve for a hard soap made exclusively from tallow; but for various reasons it is often found desirable to use a mixture of fats or oils, or even of rosin. Castor oil possesses the advantage of readily saponifying, and forming a very hard product, which will take up a large per-centage of water. Cocoa-nut oil has the same characteristic; but it has other specialities, which will be considered presently, when speaking of marine soap. Palm oil is suitable for toilet soaps, an admixture of it communicating a rather agreeable perfume. It may be used to advantage to the extent of 75 per cent. of palm oil to 25 per cent. of tallow.

Rosin will not make a hard soap by itself, as it has too great an affinity for water—so much, indeed, that after having been dried it will become liquid on exposure to the air. It makes, however, a very good compound, either with tallow or palm oil, if limited to about 15 per cent. In no case should it exceed 30 per cent. The rosin should be saponified separately from the fat, and then added to the other after the last boiling described above, continuing the boiling for some time afterwards, until the two preparations have thoroughly combined. Rosin being cheaper than the other substances, the yellow soap thus made has an advantage in price, while for ordinary washing purposes the slight smell peculiar to rosin is not an objection. It, moreover, makes an excellent lather, and is a strong, useful soap.

Oleic acid is very readily saponified, and requires much less boiling than the other substances already mentioned. It may be used either alone, or with tallow or rosin. It makes a good soap, firm, and not affected by the weather.

Olive oil is largely used in the south of Europe instead of tallow, the shores of the Mediterranean being the native soil of the olive. In this country, however, it cannot compete in price with the other articles above named.

Considerable stress is often laid upon having mottled or marbled soaps, and not altogether without reason, because it is not so easy to give them this appearance when containing a large proportion of water. Twenty per cent. may be taken as about an ordinary per-centage in the mottled descriptions. The salts of iron or copper (especially the former) are most generally adopted to produce this effect, which is due to their natural tendency to separate more or less from the mass of soap with which they are mixed, as it cools. If the cooling proceeds rapidly, sufficient time is not allowed for the interchange of the particles, and the soap will present a uniform hue of the colour characteristic of the metallic salt employed. If it is cooled gradually, veins and patches, of a bluish colour in the case of iron, will afterwards be found to extend throughout the mass, which will turn to a reddish colour by the oxidation of the iron on subsequent exposure to the air. It is the conversion of the sulphate into the oxide which furnishes the red mottling of the Castile soap on the exterior surface, while it is of a bluish-black within. If the soap were too watery, the colouring substances would, by their superior weight, find their way to the bottom of the boiling-pan, and the effect desired would be entirely lost.

Fancy soaps, which are made in great variety for the toilet, are usually scented with some aromatic oils. For this branch of the trade the ordinary commercial soaps are used, after undergoing a process of refinement, or a soap is specially made for the purpose from almond oil, or the like. Much taste is shown by the best London makers in the selection and combination of the perfumes, which, along with the colouring matters, such as vermilion, yellow ochre, aniline, etc., are usually boiled up with the soap. To facilitate this operation, as a well-dried soap does not readily melt, it is usually cut up into fine shavings, and after boiling is well worked under rollers until it presents a uniform appearance. If the soap is intended to be highly scented, or very expensive perfumes are to be employed, the cold process is adopted, as much of the strength of the scent is lost by boiling. In this case the soap is shredded as before, and the perfume and colouring matters well amalgamated with it by being worked in a mortar with a pestle. It is then divided into lumps, and roughly moulded with the hand into something of the shape it is finally to assume. After being left on a rack to dry for about a week, it is pressed into a mould, which imparts to the cake the form and device which may be required, and when taken out the edges are trimmed and the surface polished with the hand.

Transparent soaps are prepared by taking an ordinary hard soap and dissolving it in hot alcohol, after having stored it for the purpose of driving off all the water. Soap being completely soluble in this medium, any extraneous matters which it may contain can be readily separated by filtration, care being taken to keep the solution hot during the process. The alcohol is then evaporated out of the filtrate, and on cooling it hardens into a transparent soap. These soaps are coloured, according to fancy, with vegetable colours dissolved in alcohol. This branch of the trade is little practised in England, in consequence of the heavy duty on spirits, which prevents the home manufacturer from competing with those on the Continent.

Soft soaps are made in this country with either potash or soda and the drying oils, the most familiar of which are those extracted from hempseed, rape, and linseed. These oils are deficient in stearine, and on that account are not available for hard soaps. On the Continent potash is much more frequently employed as the alkali instead of soda, potash being comparatively cheap in those countries where wood abounds; but it has such an affinity for water that even when combined with tallow or the non-drying oils, it will not make a firm soap such as will retain its character in a moist atmosphere.

In this manufacture the non-drying oils, or sometimes the fish oils or tallow, are boiled up with a solution of potash, not too strong, until they form a thick sticky fluid, when a stronger lye is added and the boiling continued until it becomes quite clear and slimy. The compound has now to be tested carefully, to see whether there is a proper proportion between the fatty acid and the alkali; because an excess of either the one or the other will become evident on cooling. Having adjusted this properly, the heating is continued, in order to drive off the superfluous water, and the process is accelerated by keeping it constantly stirred. As the evaporation of the water progresses, the substance in the pan becomes thicker, and the froth on the surface diminishes, until the soap settles down in a thick mass at the bottom. The heat is then withdrawn, and when the

contents of the pan have cooled down they are scooped out and put into casks.

Soft soaps, according to quality, contain from 40 to 50 per cent. of water. Sometimes they present the appearance of a clear yellowish jelly interspersed with small grains, which is produced by the addition of a little tallow, the less soluble constituents of which collect in small granules. At other times they present a uniform green colour, which is a natural result if the soap has been made from hempseed oil, but which is often produced artificially by the admixture of indigo in a yellow soap. Both the colour and the granulation are mere fancies in the trade, and have no other necessary connection with the manufacture.

With the drying oils, soft soaps may be made with soda; other fats and oils besides those already named may be used with a mixture of soda and potash, in which the latter predominates.

The hard soaps should be as nearly as possible neutral; but the soft cannot be separated from the lye by the addition of salt, as in the former, so that they always retain an excess of alkali. They are principally used for scouring manufactured goods in the bleaching and dyeing works, and will be found mentioned in Lessons I. to IV. of this series, which treat of such operations.

Marine soap is made of cocoa-nut oil. Whilst a very small quantity of salt will separate the curds produced by the saponification of any other oil, it has no effect upon this. A very strong brine is necessary for the purpose; but that is found to be unsuitable in practice, as the brine takes up the water at the same time, and leaves so hard a curd as to be unmanageable. It has such a tendency to harden under any circumstances that the oil is boiled with the very strongest caustic soda lye, care being taken that the alkali be not in excess, in which case the use of salt can be altogether dispensed with. The operation is facilitated by the replacement of some of the soda by potash. A cocoa-nut soap made with soda will hold upwards of 70 per cent. of water, and still be so firm as to deceive the uninitiated; however, it is, of course, proportionately weak in its cleansing properties. Its resistance to the effect of a weak solution of salt indicates its value on shipboard, other soaps being absolutely useless for washing in sea-water.

Incredible as it may appear, flints, sand, or pipe-clay may enter pretty largely into the composition of soaps, both hard and soft, and that without injury to their useful properties. The silica contained in them is reduced to a soluble state by being melted in a reverberatory furnace with caustic soda or potash, then ground fine, and lastly boiled in an aqueous solution of the alkali, the result of which is that the silica forms a transparent gelatinous mass, sometimes known by the name of soluble glass. When the soap has been thoroughly boiled, the silicate of soda is mixed with it in the pan, and the compound is then transferred to the frames to cool and harden. As in the other processes, potash is only used when a soft soap is intended to be made. These soaps are cheaper than those made exclusively from oils and fats, while at the same time they fulfil their purpose very satisfactorily.

TECHNICAL DRAWING.—XXIII.

THE TEETH OF WHEELS.

FIG. 229.—*To trace a cycloid* by mechanical means.*

Fasten a rail of wood, or any straight edge, to a board.

Take a circular piece of wood, cut a small notch at any point in the edge (as at A), and fix a small knob or button in the centre (B).

The point of a pencil held in the notch, whilst rolling the disc along the straight edge by means of the knob, will describe a cycloid.

In order to prevent the disc slipping as it rolls along, it is advisable to glue a narrow strip of sand-paper round the edge of both disc and rail.

If, instead of a straight piece of wood, a circle or arc be employed, the curve traced by the pencil will be an epicycloid; if the inner side of a hoop be used, the curve will be the hypocycloid.

Now if the same generating circle be made to roll on the outside of a circle, and again on the inside, both curves starting from the same point, the portion inside the circle (the hypocycloid) will give the curve for the flank of the tooth, and the cycloid on the outside will give the face or point of the tooth.

This will be clearly understood when put into practice, and for this purpose the attention of the student is directed to Fig. 230.

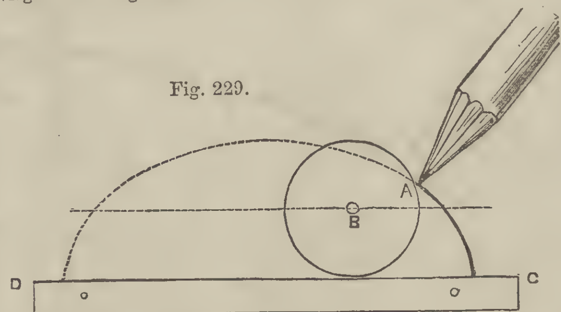
In this figure A and B are the centres from which the pitch-circles A′ A″ and B′ B″ are struck. These circles touch each other at C.

Now if the epicycloid C D be drawn from C, then a portion of it, C F, will be the face or point of the tooth; and, again, if by means of the same generating circle a hypocycloid, E C, be traced from the same point, the portion C G will be the flank of the tooth. Of course, if similar curves are drawn from H, in the reverse direction, the opposite side of the tooth will be described.

The length comprised by a tooth and a space is called a *pitch*. This is, of course, equal to the distance from the centre line of one tooth to that of the next one.

The following data are those generally adopted by millwrights and engineers:—

Fig. 229.



Supposing the "pitch" to be divided into 15 equal parts; that is to say—

Height of tooth outside the pitch-circle	$5\frac{1}{2}$	parts.
Depth of tooth within the pitch-circle	$6\frac{1}{2}$	,,
Thus the total height of the tooth is	12	,,
Width of tooth	7	,,
Width of space between the teeth	8	,,

Some engineers, however, adopt the following proportions, and they are, therefore, used occasionally in the examples:—

The pitch divided into	11	parts.
Width of space	$\frac{6}{11}$	,,
Width of tooth	$\frac{5}{11}$	,,
Depth of flank	$\frac{4}{8}$	,,
Height of face	$\frac{3}{8}$	,,

Although teeth are designed and the patterns for them are made on the scientific principles shown, it is usual in most drawings to consider the curves as portions of circles, which may be drawn with such approximate correctness as to be sufficiently accurate for general purposes of drawings—the length of a pitch being, as a rule, taken as the radius. The face of the tooth, A E (Fig. 231), is struck with this radius (the pitch), and the flank, A D, is struck from C, the centres being in the pitch-line B.

Now it will be noticed that the flank of the tooth under consideration bends inward about the middle, between A and D. This may be avoided by employing a circle of centres—that is, a circle a little outside the pitch-circle—and although using the pitch as the radius, fixing the centres on this additional circle, Thus, place the steel point of the bow compass at F on the additional circle, but strike the flank from G.

It will be seen that by these means the evil alluded to is avoided: the tooth thus becomes broader at the base, and consequently stronger.

It will be found that when the diameter of the generating circle is equal to the radius of the circle in which it rolls, the hypocycloid is converted into a straight line; therefore, when

* The cycloid was invented by Galileo, an eminent mathematician and natural philosopher. He was born in Pisa in 1564, and died in 1642.

the one wheel is of half the diameter of the other with which it is geared, the flanks of the teeth, instead of being curves, are straight lines tending towards the centre, and they are hence called *radial* teeth. Two such are shown in Fig. 232.

As teeth so formed are, however, necessarily narrower at the

Draw the pitch-circles, touching each other in T.

From T set off a pitch on each of the pitch-circles—viz., T A and T B.

Join A and B. Bisect A B by the line C, and produce it.

From A draw the radius A D.

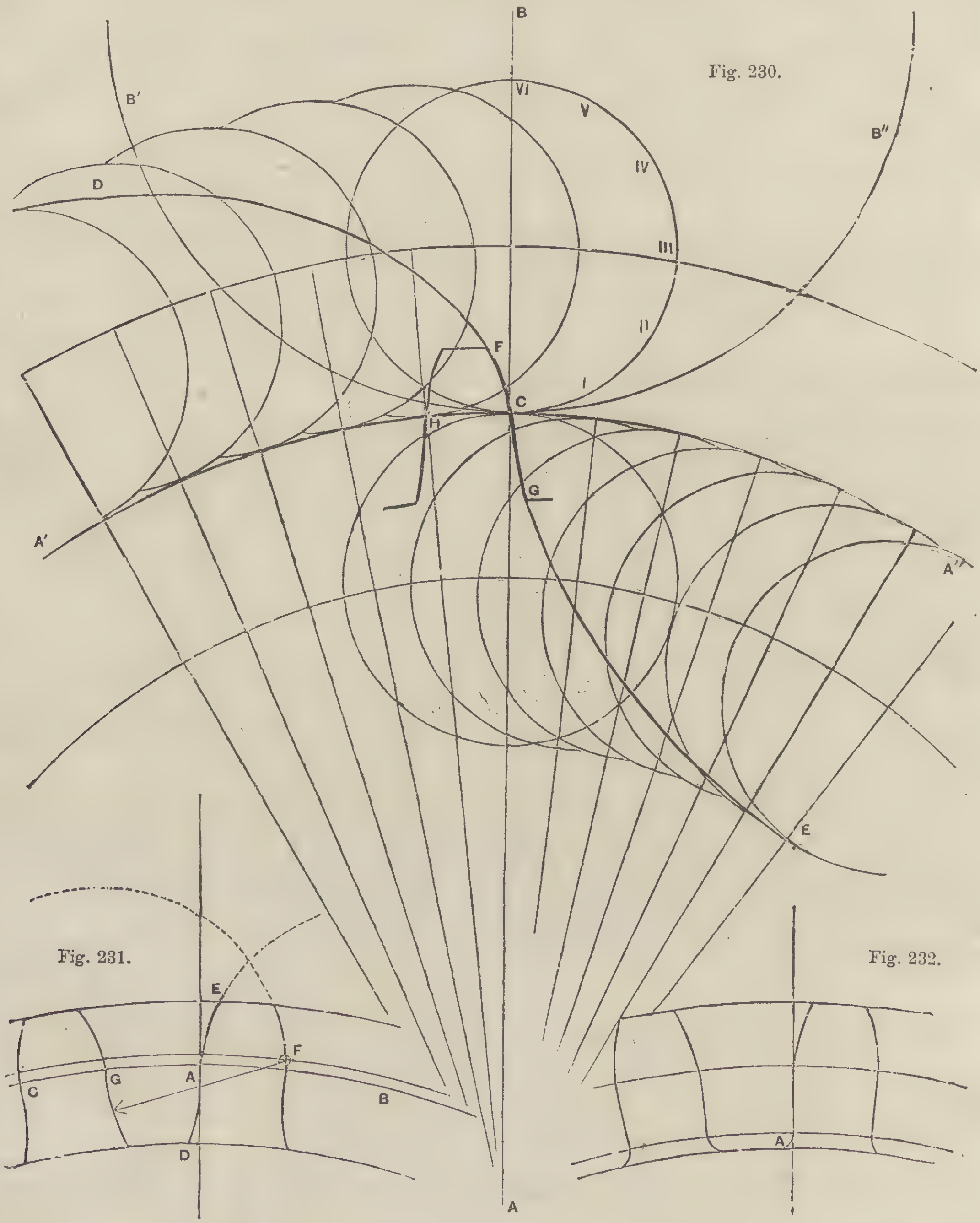


Fig. 230.

Fig. 231.

Fig. 232.

bottom than on the pitch-circle, they would be weaker at that part, the radial flanks are not drawn quite down to the root, but are turned off by small quadrants, by which means they are materially strengthened: this is shown at A in Fig. 232, and will be further illustrated in future examples. In order to strengthen the teeth, flanges are sometimes cast on one or both sides.

Fig. 233.—*To draw radial teeth to gear with each other.*

From B draw the radius B E.

At A draw a line at right angles to A D, cutting the bisecting line C in F.

At B draw a line at right angles to B E, cutting the bisecting line C in G.

From the centres of the circles to which these tangents are drawn, draw circles through F and G, and these will be the circles of centres for the faces of the teeth.

Now set off the pitches around the pitch-circles, and divide them into teeth and spaces. In the present example the tooth is taken at $\frac{5}{11}$ and the space at $\frac{6}{11}$ of the pitch, the height outside the pitch-circle being $\frac{3}{8}$ and within the pitch-circle $\frac{4}{8}$ of the pitch.

The radial flanks are now to be drawn, and turned towards the bottom by means of arcs, as directed in Fig. 232.

Fig. 234 is inserted to remind the student of one of the methods of dividing a line proportionately to another.

In this figure let A B represent the length of the pitch, which

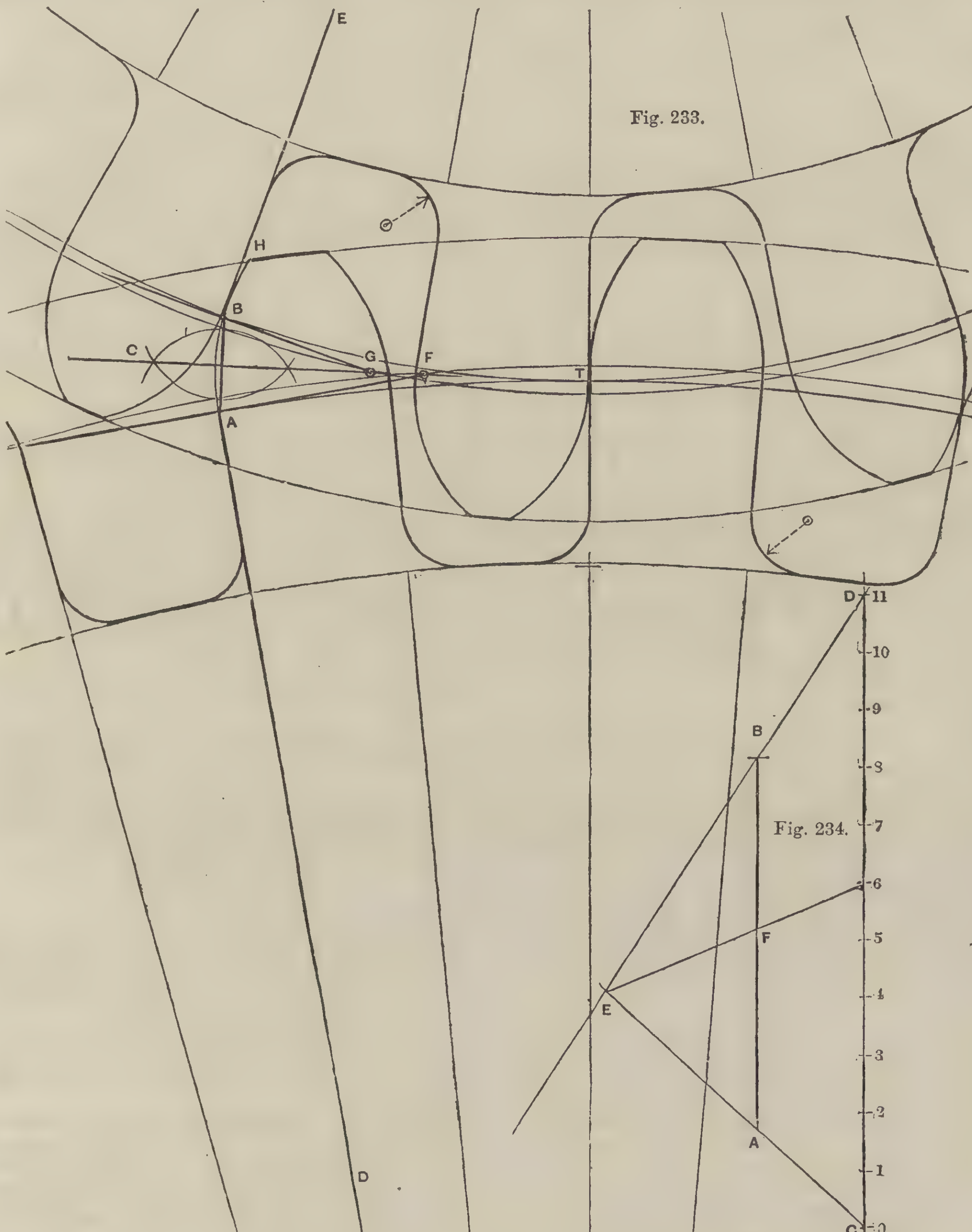


Fig. 233.

Fig. 234.

Draw the circles in the way which has frequently been shown for the root and points of the teeth.

From F, with radius F A, describe the arc A H, which will be the face of the tooth; and with this radius, and from the same circle of centres, the faces of all the rest of the teeth of the large wheel are to be struck.

The faces of the teeth of the smaller wheel are to be struck with the radius G D.

it is desired to divide in the proportion of five-elevenths and six-elevenths.

Draw any line, C D, parallel to A B, and set off upon it eleven spaces. These may be any length.

Draw lines, D B and C A, uniting the ends of the two lines, and meeting in E.

From the point marked 6 draw a line to E, which will divide A B in F in the desired proportion.

TECHNICAL EDUCATION ON THE CONTINENT.—XII.

BY E. A. DAVIDSON.

FRANCE (*continued*)—METHOD OF TEACHING DRAWING.

PRIMARY instruction developing itself in adult classes gives to the apprentice and artisan elementary notions of science, which they can apply in their various occupations. Secondary special instruction further develops these germs, and increases in use as the artisan learns the application of science to the work on which he is engaged.

But we would have it very clearly understood that we do not mean to imply that technical education can ever do away with apprenticeship. The variety of work which a lad sees going on around him in a workshop—the adaptation of machinery and tools—the broad way in which work is "cut out" and arranged—the division of labour, and above all, the curb which is put on during the years when he is passing from boyhood to manhood, and the tie by which he is held to regular occupation—all render a term of apprenticeship of the utmost importance to a youth.

Technical education, then, is meant to assist, not to supersede apprenticeship, by giving a youth a knowledge of scientific principles, the application of which he learns practically in the workshop.

Instruction of this kind had been going on in France long before it was really known as such. The Government, in order to meet the varied national wants, long since organised various establishments where professional apprenticeships were carried out practically. The schools of agriculture and the farm schools, the schools of arts and manufactures, the naval school, etc., are established for technical education of the most approved kind. Private enterprise did more, and an inquiry has made known the useful creations of industrial societies, of large companies, of chiefs of works, of heads of institutions, and of congregational establishments, which have, in the opposite parts of the country, realised the apprenticeships of various industries with much success. But in the face of the ever-increasing mass of wants, legislature became necessary to encourage and regulate the technical education which has now become general.

Before mentioning any special systems of actual education, we must refer to one of the means employed, without which education cannot be carried on—namely, the diffusion of books. The *colportage*—that is, the sale of books by hawking, or otherwise than in shops—can neither diffuse them in sufficient numbers, give adequate extension to circulation, nor place them in all hands. Its business is trade, not education, and even managed as it is, it cannot furnish sufficient guarantee for regularity or continuousness of delivery.

The establishment of libraries in all the communes of France, lending or hiring out books, placing them within the reach of all, was a necessary means to be taken in the promulgation of education. Set on foot by the Minister of Public Instruction, established in the communal schools, kept by the schoolmaster, the scholars' libraries were the first established. There are now about 8,000 libraries, which lend out 500,000 books per annum. But the ministerial action was not enough to endow 4,000 communes with libraries, and public spirit came in aid with remarkable alacrity. A great number of free societies have been formed for this special object, some including a whole province, others a department, and the rest purely local in their action. Many in Paris have striven to organise for themselves centres of action, from which to operate on the country around, either in giving their assistance in the formation of libraries, or in making known and encouraging good books, or by influencing the colportage. Whatever may have been the extent of their operations or the mode of their action, they have all assisted in maintaining a healthy agitation which has already borne good fruit. Not only have thousands been induced to read who never before touched a book except by accident, but publishers having thus a large market opened to them, and authors finding a public always ready for their works, have prepared them specially for the object to be attained; the former, by more economic arrangements, have endeavoured to reach the perfection of cheapness; whilst the latter comprehend that, in order to reach the soul of a whole nation, literature must separate itself from elaborations of style, and be pure and broad in its principles; that in order to teach the million, the writer must not from the summit of an eminence declare the advantages of the elevated position to those who have only imperfect means of attaining it, but that, placing his foot on the lowest step of the ladder, he must take his less favoured brethren by the hand, and say, "Let me lead you up;" that he who would write for working men, must throw his whole heart into his work—must write clearly, simply, and, above all, honestly.

It is obviously impossible, in a series of papers such as these, to give detailed accounts of each of the great schools for technical instruction in France; the mere mention of *all* would occupy the remainder of the space at our disposal. One of those in which the industrial work is of an excellent and practical character, is the École Municipale de Dessin Industriel at St. Quentin. We were shown an admirable drilling machine, ornamental wrought-iron gates, a spiral staircase in wood and another in iron, a crab, various doorways with panelled doors, a carved wooden pulpit, etc., all the actual hand-work of the students, and in most cases the working drawings from which the articles had been made were exhibited. In the École Professionelle de Mulhouse, the mechanical works carried on are on an extensive scale. The tendency of the studies seems to be in the direction of mechanism, the works produced being principally of that character; amongst these are vices, screw-hammers, lathes, various other tools and mechanical appliances, models of machines, all executed with the utmost accuracy and in the most workmanlike manner, all showing the knowledge of the principles involved in the construction. Again, in the École Impériale d'Arts et Métiers, at Chalons, the system of practical application of science is admirably carried out, and the students are taught pattern-making in wood. We saw the pattern for a bevel wheel six feet in diameter, also spur, face, cog, band, and fly-wheels; but it must not be supposed that the works of the students are limited to wood, or even to mechanical subjects. Their work in both cast and wrought iron is admirable in character—plummer blocks, hangers, cams, etc.—whilst in their artistic department they produce bronzes of whole figures, such as Napoleon, Britannia, Apollo, etc., in which the modelling and casting are equally good.

Perhaps, however, the greatest triumph of work based upon scientific drawing was a large group of objects shown in the Paris Exhibition in 1867. It was labelled "Models made by the Chiefs of the School Workshops, from the drawings of the students, designed for practical instruction in mechanical drawing." These models consist of various apparatus, appliances, mechanical movements, tools, etc., and can be used therefore not only in teaching mechanical drawing (all being constructed to correct scales), but also in illustration of lessons on processes, physics, etc. Amongst them is a furnace which may be divided to show the vertical section; engines of various kinds, a forge, etc. etc. Thus is the labour well directed; and it must be encouraging to students to work from models designed and partly made by others—it must tend to give them confidence in the system, and in their teachers, without which education cannot be carried on with energy or success. We must pass by (for the reasons already stated) the École Speciale de Cluny, the professional schools at Ivry-sur-Seine, and at Vincennes (all of which carry on a system of technical education of the most practical character), and give a description of the system of teaching drawing to children and adults, which is largely carried out on the Continent, especially in primary and secondary schools in France.

It will not, it is hoped, be deemed out of place here to devote thus much attention to this subject, when it is remembered that drawing is one of the most important elements in technical education, that it constitutes the language of form by which men of every nation can communicate with each other, and that therefore the methods by which it can be best taught must be worthy of serious consideration.

It must be remembered that, until within very recent date, the subject of drawing has been treated in most countries as a branch of education of a lower character than any other; the instruction consisting for the most part in giving the student a copy, which he was expected to imitate, to measure the lines, to shade where his example was shaded, and to colour where he saw colour in the copy.

Many excellent systems gradually dawned, and have been adopted in Germany and other countries; none, however, seem

so well adapted to the wants of absolute *beginners* as the one originated and admirably carried out in the system about to be described. Many previous courses of drawing, though learnedly conceived and well executed, failed to attain the results intended, especially in regard to *public* instruction.

It is clear that when the pupils in a large class have each a different copy, it becomes impossible for the teacher to do more than give to each a passing word as to the execution. He has not time to explain principles, whilst the work of the student is reduced to a merely servile process of copying, the results being obtained in the best way he can; sometimes, in fact, beginning at the end, and filling in the constructive lines afterwards. The writer has often seen students who have been working perspective or projection from a printed diagram, where they know the form of the object, *draw* it first, and put in the lines of which they do not know the reason or purpose afterwards!

Further, in giving students a finished drawing to copy, they do not learn the principles upon which the representation has been constructed; and experience has shown that many who can copy a drawing with exactitude and neatness, are utterly unable to produce even a fair representation from the object itself. Of course the success in teaching drawing to the young must, in a great degree, depend on the general cultivation of their intellectual faculties; but, again, if this subject be well taught, it may be made a useful handmaid to all other education, since its applications are so varied and its results so interesting.

To accomplish these results, however, experience has shown that in classes of either children or adults, the following conditions are necessary :—

1. That the master's lessons should be simultaneously given to all pupils in a class or section, and that for this purpose the subject must be drawn on a large scale.
2. That from the explanations given by the teacher, the pupils should be led by observation and realisation to the object itself, for which purpose well-made and well-selected models should form a part of the course.
3. That in the first year of the course the teaching, being intended for children whose ages vary from ten to twelve years, should be of a character so elementary and simple as to be adapted to their capacity, but still be the basis of the higher instruction to which it forms the introduction.
4. That in the second year, a technical tendency should be given to the instruction, agreeing either with the industries of the locality, or with the career for which the pupil is intended; where this is not ascertained, a general knowledge of architecture, mechanism, etc., to be given.
5. That the means employed should, whilst engaging the pupils, aid the teacher in his instruction, and furnish him with all that can render the study attractive and pleasant to the pupils.

It is evident that a course fulfilling these conditions must be profitable, since it calls for the exercise of intelligence, observation, and thought, whilst it produces that legitimate satisfaction which must result from the exercise of the intellectual faculties.

How much latent intelligence, how much mental power, would have been awakened in the working men of a past period, had such light been thrown over the instruction of their childhood! Whereas the intellect was thrown back on itself, because it was not cultivated in a manner favourable to its development.

The appliances for carrying out this system are :—

1. A very large set of diagrams, so that the pupils may see at a glance the whole subject they are to draw, and to enable the master to give the necessary simultaneous instruction, in which he also, if able, uses the blackboard for drawing rapidly any detail which may seem to require further development. To aid the teacher in his explanations, he is furnished with books with corresponding illustrations, serving, in fact, as well-worked out notes of the lesson.
2. Solid models of a good size of the subjects to be drawn, which the students can handle and examine, and so see the reason of lines in the drawing.
3. A separate book for each pupil, in which the subject of the diagram is given, in order to lead to quiet individual study at the class or at home. The illustrations are for the most part rough sketches, figured as to sizes, which the student is required to work out on a given scale.

Now the results of such a system must be, that it accustoms the pupils to consider the relations between the dimensions of a subject, and teaches them the method of representing it by means of properly disposed lines, and in a given proportion as to size. It creates in them a desire to inquire into the construction of the object, a knowledge of which in all its bearings enables them the better to delineate it from points of view other than the one which for the time engages them; it accustoms them from the beginning to make practical and useful drawings, such as will be understood by all persons engaged in the various branches of industry; and, further, it affords them the satisfaction of having really by their own efforts *made* a drawing, instead of having merely *copied* one.

The whole of this system, together with others which have been found in every respect most successful on the Continent, will be carefully worked out in the TECHNICAL EDUCATOR.

PRACTICAL PERSPECTIVE.—III.

FIG. 14 is a representation of the interior of a hall, having a floor covered with square slabs of alternate white and black.

This view is not drawn to any particular scale. Having drawn the general outline or rectangle, fixed the centre of the picture, and drawn the horizontal line, the points of distance must next be marked. These (as in the present illustration) need not be on the paper, but may be on the board or table on which you are drawing.

From the four angles of the figure draw lines to the centre of vision, which will give the lines of junction between the floor and ceiling and the walls.

Now this hall is supposed to be twice as long as it is wide. The floor thus consists of *two* squares.

Therefore, from A and B draw lines to the points of distance. These will give the points C and D. Join C and D, and this will complete *one* square of the floor.

Again, from C and D draw lines to the points of distance, and these will give the points E and F.

Draw E F, then A E F B will be the perspective representation of the floor.

From E and F draw perpendiculars, cutting the upper edges of the wall in G and H.

Draw the lines G H, which will complete the view of the interior. The windows and doors are necessarily omitted in this study.

Now divide the line A B into the number of parts corresponding with the number of slabs to be placed on the floor, and from these points draw lines to the centre of vision.

It will be seen that these lines, 1, 2, 3, 4, 5, 6, will pass through the diagonals A D and B C, and also through C F and D E.

Thus lines 1 and 6 will cut the diagonals in *a* and *b*. Through these points draw a horizontal line, which will give the front row of squares. Lines 2 and 5 will cut the diagonals in *c d*. Through these points draw another horizontal line, which will give the second row of squares.

Lines 3 and 4 will cut the diagonals in *e* and *f*. Through *e* and *f*, therefore, draw a horizontal line, which will give the third row of squares.

By continuing this method, the entire surface of the floor will be covered with squares, each diminished in size or altered in form according to its position.

The system of working by scale having been shown in several of the earlier studies, it will not be necessary to our purpose to give the measurements in every case; but it will be evident that all the principles of perspective here laid down can be equally well applied, whatever may be the relative size of the objects or the height of the spectator. All measurements in the future figures are therefore assumed, leaving it to the student to work them to any scale he may think proper.

Fig. 15.—In this study it is required to put into perspective a square, the surface of which is at right angles to the plane of the picture, and which is divided into nine equal squares.

Having drawn the picture-line and horizontal line, and having

fixed the centre of the picture and the points of distance, set off from A the length A A′, representing the distance of the front edge of the square on the left of the spectator. Make A′ B equal to the height of the required square, and from A′ and B draw lines to the centre of the picture. From A′ set off on the picture-line A′ D equal to A′ B. From D draw a line to the point of distance, cutting A C in D′.

At D′ erect a perpendicular, cutting B C in C′. Then A′ B C′ D′ is the perspective representation of the square placed at A′, at right angles to the picture-plane. Divide A′ B into three equal parts by the points E, F. From E and F draw lines to the centre of the picture, cutting C′ D′ in G and H.

These lines will divide the squares horizontally into three equal strips.

Divide the length A′ D into three equal parts by the points I, J. From I and J draw lines to the point of distance, cutting A′ D′ in I′, J′.

At I′ and J′ erect perpendiculars, cutting B C′ in K and L. These will divide the perspective view of the square vertically into three strips, and these will become gradually narrower as they recede, although representing spaces of equal width.

Another method of dividing the square would be to draw diagonals. Then the lines E and F, cutting these, would give the points through which the lines I′, J′ should pass. This method is only of use, however, where the figure to be divided is a *square*, whilst the method shown is equally applicable to any parallelogram.

Fig. 16.—This is an application of the foregoing figure, and represents a wooden case divided into compartments. Having marked the point M, representing the distance of the front of the object from A, draw the parallelogram M N O P, which shows the depth of the side of the case.

Draw the perspective view of the front of the case as in the last lesson; then, instead of dividing it into three equal parts, as in the line A′ B in the previous figure, set off upon the line corresponding with A′ B the spaces representing the thickness of the wood of which the carcase of the case and the shelves are made, and draw lines from these points to the centre of the picture.

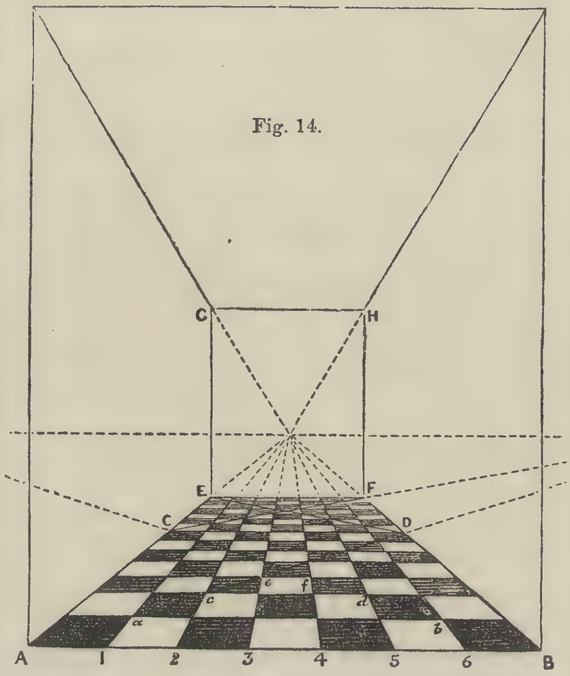


Fig. 14.

Next set off within the space on the picture-line which represents the real width of the lower edge of the case the thickness of the sides of carcase, the upright partitions, and the distances between them. From these points draw lines to the point of distance, which, cutting M C, will give the points at which vertical lines are to be drawn.

In this study the case is represented as square; but the method of working would be the same, whatever might be the proportion of the breadth to the height.

The horizontal lines showing the junction of the sides of the compartments will complete the object.

EXERCISE 8.

There is a case of shelves against a wall: the case is 8 feet high and 4 feet wide; it has three shelves placed so as to divide the case into four equal spaces. The wood of which the case and shelves are made is 1 inch thick; scale, 1 inch to the foot. The height of the spectator is 5 feet 6 inches, and his distance 15 feet. The front of the object is to be parallel to the picture-plane, at 6 feet on the left of the spectator.

EXERCISE 9.

Give a perspective view of the same object when at 10 feet on the right of the spectator, and 8 feet within the picture, when its front is at right angles to the picture-plane. Height of spectator, distance, etc., the same as in the last exercise.

Fig. 17.—In this study only a portion of the picture-plane is used; the centre of the picture being placed at one side, and the point of distance at the other.

The subject of the study is a cube, placed first in the foreground, and then at different distances within the picture.

The length from A to B represents the distance of the cube to the left of the spectator, and B C′ is the length of its edge.

From C′ and B draw lines to the centre of the picture; and, as shown in Fig. 13 (1), the cube, as it moves backwards at right angles to the picture-plane, will travel in this track.

From B set off D, equal to the side of the cube, and draw a line to the point of distance. This line drawn from D will cut B C in D′; and a horizontal line from D′ to cut C C′ in C″ will give the distant edge of the ground-plan of the cube.

It will next be advisable to draw the perspective views of the ground-plans of the two other views of the cube.

From D set off D E, equal to the distance between the back of the first cube and the front of the second. Draw a line from E to the point of distance, which, cutting B C in E′, will give the position of the second cube; and a horizontal line drawn from E′, cutting C′ C in E″, will be the front edge of the plan.

It will thus be seen that E′ E″ represents C′ B when it has receded to the given distance.

Now a line drawn from E to the point of distance, cutting C′ C in F, would be a diagonal of the square base of the cube. Therefore a horizontal line drawn from it would give F F′, and complete the plan. But, as already remarked in the former figure, this method would apply to the square only; and therefore another method is shown—viz., set off on the picture-line from E the *real* length of the distant side, whatever that may be. The point F is outside the present figure; but the line drawn from it to the point of distance will be seen to cut B C in F′, which gives the position of the back line of the plan. The third plan is to be drawn in a similar manner—viz., by setting off from the last point on the picture-line the distance of the next cube and the width of its side, and drawing lines to the point of distance, cutting B C in G′ and H. Then, as in the previous case, horizontal lines will give the front and back edges of the plan required.

Now on C′ B construct a square, representing the front of the first cube; and from the two upper angles, I and J, draw lines to the centre of the picture.

On E′ E″ and G G′ erect perpendiculars, and these will be cut by I C and J C at the required height. Horizontals being then drawn at the points where the perpendiculars are cut off, will complete the fronts of the two distant cubes.

The perpendiculars D′, F′, and H will give the distant edge of the side of each cube, and the position of the rest of the lines to complete the transparent appearance of the objects will be readily understood from the diagram.

EXERCISE 10.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 15 feet.

(1.) Put into perspective a cube of 4 feet edge, when its front is parallel to the picture-plane, at 6 feet on the left of the spectator, and 5 feet within the picture.

(2.) Put into perspective a cubical figure 2 feet square at base, and 9 feet high, when at 8 feet on the right of the spectator, and 10 feet within the picture.

Fig. 18 is a cubical figure, or block of stone, which is much higher than the eye of the spectator; and for this reason the top, of course, cannot be seen. In order, however, to account

for this appearance, the object is drawn as if transparent, and thus the upper surface of the bottom and the under surface of the top become visible. The student is recommended to work all his figures in this way, as the interior lines act as a check on the exterior ones, and many inaccuracies are often thus discovered.

In order that the student may test his present knowledge of the method of working pursued, these figures are not lettered; but all the working lines are clearly shown, and the construction will now be described.

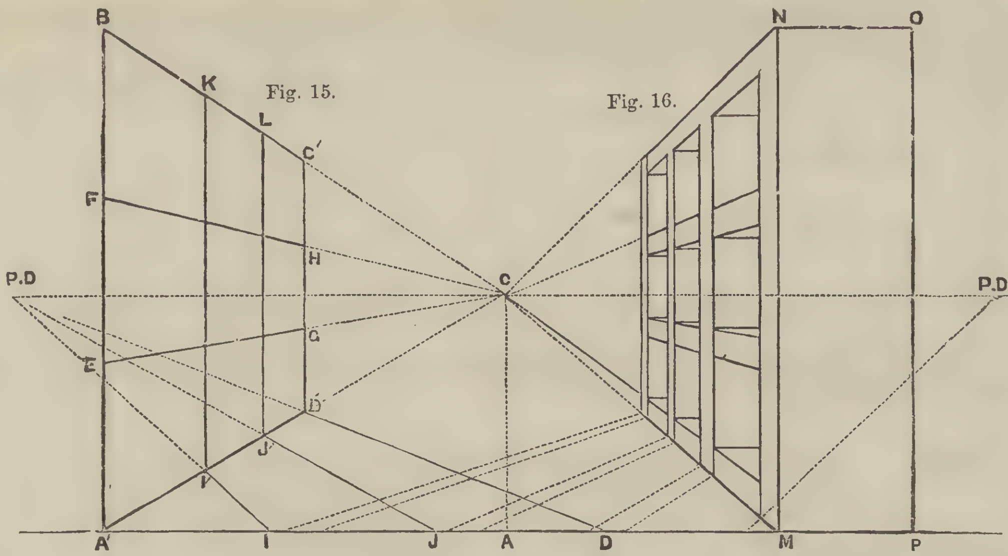


Fig. 15.

Fig. 16.

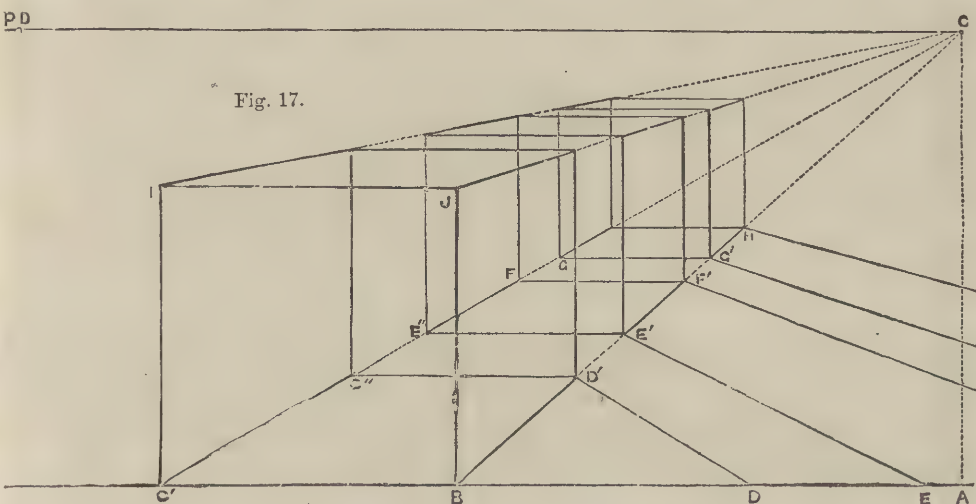


Fig. 17.

The base of the block is a square, and it is placed on the left side of the spectator, at a distance which may be assumed, or which would be named in the question to be worked.

Whatever this distance may be, set it off on the picture-line from the point immediately under the centre of the picture; and from this point again set off the width of the square base.

From both the last-mentioned points draw lines to the centre of the picture; then from the first one set off the real length of the distant side of the base, and draw a line to the point of distance; this will cut the line drawn from the end of the front of the base to the centre of the picture, and will give the point at which the horizontal line forming the back edge of the plan is to be drawn.

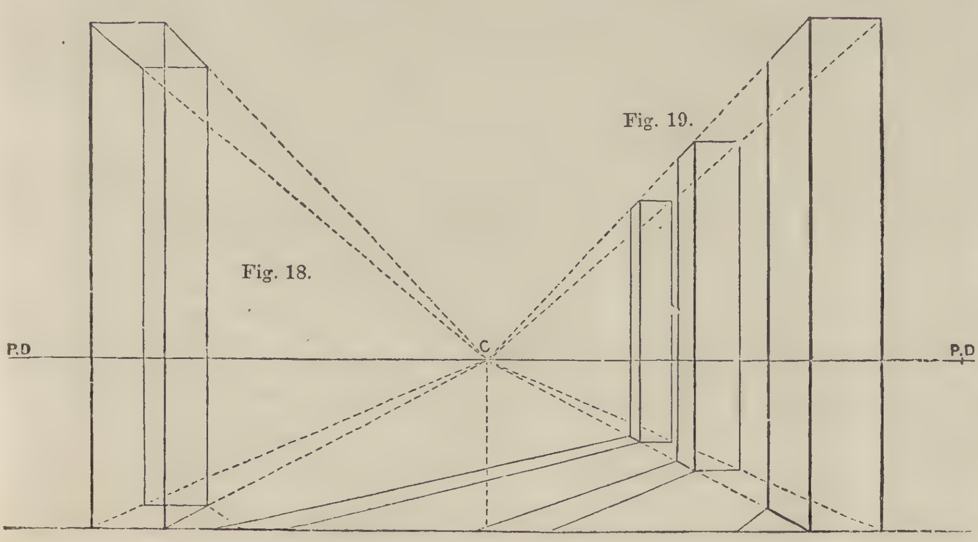


Fig. 18.

Fig. 19.

Now draw the front elevation of the block of such height as may be required, and from both the upper angles draw lines to the centre of the picture. The distant perpendicular is then to be drawn from the back angle of the base, and the interior lines will then follow in their places.

Fig. 19.—This figure will afford further practice in placing objects in the distance, and the principle having already been fully explained in relation to the figures, it will merely be necessary to pass rapidly through the directions for working this study.

Having drawn the plan as in Fig. 18, mark off on the picture-line the distance between the columns; draw lines from these points to the point of distance, and these, cutting the line drawn from the end of the front edge of the base, will give the positions for the bases of the distant columns.

From these plans erect perpendiculars, which will be terminated by the lines drawn from the upper angles of the object in the foreground to the centre of the picture, and these being connected by horizontal lines will complete the view.

NOTABLE INVENTIONS AND INVENTORS.

VIII.—POTTERY AND PORCELAIN (*continued*).

BY JOHN TIMBS.

THE essential ingredients of pottery and porcelain are silica and alumina. Pottery is opaque, while porcelain is translucent. Wares of either kind are *soft* and *hard*, distinctions which relate as well to the composition of the ware as to the temperature at which it is made solid. Common bricks and earthenware vessels, pipkins, pans, and similar articles, are soft; while fire-bricks and crockery are hard. Soft pottery consists of silica, alumina, and lime, and admits of being scratched with a knife or file. Stoneware is composed of silica, alumina, and baryta, and may be regarded as a coarse kind of porcelain. Hard porcelain contains more of alumina and less of silica than the soft; it is baked at a stronger heat, and is more dense. Soft porcelain contains more silica than the hard, and is also combined with alkaline fluxes, so that it may easily be scratched, and it is less able to resist a strong heat.

Clay is so generally diffused, and is of such plastic nature, that articles made of it may be said to belong to every people and to all times. The first drinking-vessels were, doubtless, sun-baked, and consequently very destructible; and it was not until the action of fire was discovered that permanence could be given to these articles. The sun-dried bricks of Egypt, Assyria, and Babylonia have, however, been preserved to the present day, and "not only afford testimony to the truth of Scripture by their composition of straw and clay, but also, by the hieroglyphics impressed upon them, transmit the names of a series of kings, and testify the existence of edifices, all knowledge of which, except for these relics, would have utterly perished. Those of Assyria and Babylon, in addition to the same information, have, by their cuneiform inscriptions, which mention the localities of the edifices for which they were made, afforded the means of tracing the sites of ancient Mesopotamia and Assyria, with an accuracy unattainable by any other means. When the brick was ornamented, as in Assyria, with glazed representations, this apparently insignificant but imperishable object has confirmed the inscriptions of the walls of Babylon, which critical scepticism had denounced as fabulous. The Roman bricks have also borne their testimony to history. A large number of these present a series of the names of consuls of imperial Rome; while others show that the proud nobility of the Eternal City partly derived their revenues from the kilns of their Campanian and Sabine farms" (Birch's "Ancient Pottery"). Among the Assyrians and Babylonians, clay was used as a material for writing on. The traveller Layard discovered in the palace of Sennacherib a whole library of clay books, consisting of histories, deeds, almanacks, spelling-books, vocabularies, inventories, horoscopes, receipts, letters, etc. About 2,000 of these clay books of the Assyrians have been discovered: they are in the form of tablets, cylinders, and hexagonal prisms of terra-cotta.

The potter's wheel, to give symmetry of shape to clay vessels, is represented on the Egyptian sculptures; it is mentioned in Holy Scripture, and was in use at an early period in Assyria. The very oldest wares of Greece bear marks of having been turned upon the wheel. The art of firing the ware is also of the highest antiquity. Remains of baked earthenware are common in Egypt in the tombs of the first dynasties; and the oldest bricks and tablets of Assyria and Babylon, and remains of Hellenic pottery, bear evidence of having passed through the fire. As the clay is by this process rendered porous, and incapable of holding liquids, glaze must have been early employed; and numerous fragments testify to the use of enamels amongst the Egyptians and Assyrians, and glazing among the ancient Greeks and Romans. With respect to form, the Greek vases, by their beauty and simplicity, have become models for various kinds of earthenware; while the application of painting to wares has transmitted to us much information respecting the mythology, manners, customs, and literature of ancient Greece. Even the Roman lamps and red ware illustrate in their ornaments many customs, manners, and historical events. The largest vessels of clay formed by the Greeks were the casks, one of which—and not a *tub*—was used by Diogenes for a residence when he begged Alexander to stand out of the sunshine. These casks were too big to be formed on a wheel, and so required great skill in making.

The ancient pottery has its distinctions of time and place, as between the rude urns of the early Britons and the more carefully finished specimens of their Roman conquerors. The simple, unglazed earthenware of Greece contrasts with the more elaborate Etruscan forms, the finest of which, however, are probably by Greek artists; and the red and black potteries of India contrast with the black and white potteries of North America, the latter being interspersed with bivalve shells. Among the ruins of Central America have been found specimens of pottery considerably in advance of the arts assigned to the ruins, namely, 1000 B.C. These specimens had been formed without the assistance of the potter's wheel; but they are well baked, the ornaments are in different colours, and they are coated with a fine vitreous glaze, such as was unknown in Europe until about the ninth century.

Porcelain is of modern introduction into Europe, but it was known in China more than a century before the Christian era. The Chinese improved their art during four or five centuries, and then, supposing themselves to have attained perfection, they allowed it to remain stationary. So completely was the manufacture identified with that nation, that, on the introduction of porcelain into Europe by the Portuguese in 1518, it received the name of "china," which it still partially retains. The Chinese continued to supply us with porcelain during many years. It was supposed that the fire-clay, or kaoline, used in its production was peculiar to China, and that it was, consequently, hopeless to attempt to manufacture porcelain in Europe.

While the Chinese were improving their manufacture, the art of making decorative pottery became lost in Europe. It was revived by the Mahometan invaders of Spain, whose tiles of enamelled earthenware are to be seen in the Moorish buildings of Seville, Toledo, Granada, and the Alhambra. They are of a pale clay, "the surface of which is coated over with a white opaque enamel, upon which the elaborate designs are executed in colours." The Spaniards acquired from the Moors the art of manufacturing enamelled tiles, and they still continue to be made in Valencia.

The Hispano-Arabic pottery (as it is called from being adorned with Arabic inscriptions) is the prototype of the Italian majolica, the enamelled ware of Italy, dating from the twelfth century. It is related that a pirate king of Majorca, about the year 1115, was besieged in his stronghold by an army from Pisa, and being vanquished, the expedition returned to Italy laden with spoil, among which were a number of plates of Moorish pottery. They were not imitated until the fourteenth century, when specimens of majolica—so called from the island of Majorca—were produced; they resemble the Moorish examples in having arabesque patterns in yellow and green upon a blue ground. About the year 1451 the manufacture had become celebrated at Pesaro, the birthplace of Lucia della Robbia, who is regarded by some as the inventor of this ware. His Madonnas, Scripture subjects, figures, and architectural subjects are referred to by Mr. Marryat as "by far the finest works of art ever executed in pottery." The manufacture of majolica flourished during two centuries, under the patronage of the

house of Urbino, when the most eminent artists furnished designs. There is a tradition that Raffaelle was so employed, whence majolica sometimes passes as "Raffaelle ware." The most celebrated dates twenty years after the death of Raffaelle, but his scholars used his drawings in composing designs for the finest specimens. The manufacture attained its greatest celebrity between 1540 and 1560; the art then began to decline, and the introduction of porcelain—properly so called—helped to complete its downfall. Here we may mention that of late years, majolica, in England especially, has brought "fabulous prices." The Bernal collection, dispersed in 1855, contained about 400 pieces of majolica ware, which cost Mr. Bernal less than £1,000, but realised at the sale £7,000!

Majolica prospered in France under the name of *faience*, supposed to be derived from the village of Faience, in the department of Var, which, as early as the sixth century, was celebrated for glazed pottery. The *faience* manufacture flourished under the patronage of Catherine de Medici and her kinsman Louis Gonzaga; the latter established Italian artists, who produced enamelled pottery from native materials. This declined, but in the eighteenth century it recovered, and became celebrated for the brilliancy of a dark-blue enamel, with white patterns, upon a common ware. But the pottery peculiar to France is "Palissy ware," whose inventor had considerable difficulty in bringing his ware to perfection, though after sixteen years' labour he succeeded. His rustic pottery became the fashion of the day; his style is quaint and singular, his figures are chaste in form, the ornaments and subjects—historical, mythological, and allegorical—are in relief and coloured. His natural objects, except certain leaves, were moulded from Nature. His shells are from the Paris basin, his fish from the Seine, the reptiles and plants from the environs of Paris; the colours are unusually bright, and mostly confined to yellow, blue, and grey. He is "a great master of the power and effect of neutral tints." A favourite subject with him was a flat basin, or dish, representing the bottom of the sea, covered with fishes, shells, sea-weed, pebbles, snakes, etc.

France is also celebrated for its ware known as "Renaissance," or fine *faience* of Henri II., of which there are only twenty-seven pieces extant. The manufactory is conjectured to have been at Thouars, in Touraine. The material is fine white pipeclay, seen through a thin, transparent, yellow varnish; the patterns are engraved on the paste, the hollow being filled up with coloured paste, so as to resemble fine inlaying or chiselled silver work in *niello*. A single candlestick of this costly ware was sold some years ago for £220.

Holland, from its extensive trade with Japan, was induced to imitate Japanese porcelain. The chief seat of the manufacture was Delft, and the ware was known and esteemed in the sixteenth century by its fantastic design, good colour, and beautiful enamel. The Japanese origin was seen in the monstrous animals, the three-ringed bottle, the tall shapeless beaker, and the large circular dish, which were long regarded in Europe as favourite ornaments; while the common articles were so generally distributed as to obtain the name of "Delft ware,"—in Dutch, *plaled*. These, however, have been supplanted, even in Holland itself, by the superior manufactures of England, and the improvements introduced by Wedgwood in the making of pottery. About two hundred and forty years ago, some Dutch potters established themselves in Lambeth; and, by degrees, a little colony was fixed in that village, possessed of about twenty manufactories, in which were made the glazed pottery and tiles consumed in London and other parts of the country. Here they continued to flourish till they were mostly superseded by the potteries of Staffordshire.

In England, the first manufactory of fine earthenware is said to have been erected in the reign of Elizabeth, at Stratford-le-Bow. This has long disappeared. The specimens preserved are remarkable for their lightness. The well-known Shakespeare jug—said to have belonged to our great dramatic poet—is a good specimen of Elizabethan pottery. It is of cream-coloured ware, divided lengthwise into compartments, each containing a mythological subject in high relief and of considerable merit. Fac-similes of this jug are made at Worcester. The Elizabethan pottery nearly approaches in hardness that of fine stoneware; it is dingy white, with quaint figures and foliage in relief. The Staffordshire potteries came into note in this reign; some of the earliest specimens are butter-pots of native brick-earth, glazed with powdered lead-ore, dusted on while the ware was in a green state.

In 1854 a manufactory of earthenware was established at Fulham, specimens of which are still valued by collectors as "Fulham ware," consisting of white *gorges* or pitchers, marbled porcelain vessels, statues, and figures. About the time of the Revolution, ale-jugs of native marl, ornamented with figures of white pipeclay, were introduced. During the reigns of Anne and George I., an improved ware was made of sand and pipeclay, coloured with oxide of copper and manganese, forming the well-known "agate-ware" and "tortoiseshell-ware," conferring on the pottery the character of a hard paste, which was subsequently so much improved by Wedgwood, and introduced under the name of "queen's-ware," by permission of Queen Charlotte. Previous to this period the upper classes of Great Britain obtained their porcelain from China; while the great bulk of the earthenware in domestic use was supplied by France, Germany, and Holland. To compete with these formidable rivals, Wedgwood, with persistent genius, employed the native materials which surrounded him in Staffordshire. He became a practical chemist, and improved the composition, glaze, and colour of his ware; and he invited Flaxman, the sculptor, and other eminent artists to furnish him with designs. Among Wedgwood's inventions are a terra-cotta resembling porphyry; basalt, or black ware, which would strike sparks like a flint; white porcelain, with properties similar to basalt; bamboo or cane-coloured biscuit, jasper; also a porcelain biscuit little inferior to agate in hardness, and used for pestles and mortars in the laboratories of chemists. He also imparted to hard pottery the vivid colours and brilliant glaze of porcelain. He reproduced with very great success some of the finest works of antiquity; he copied the Barberini or Portland vase, and, after executing fifty copies, destroyed the mould. His finest productions took rank with the choicest works of Dresden and Sèvres. He greatly improved stoneware, which France manufactured before the sixteenth century; and, in England, Dutch and German workmen were engaged in its manufacture at an early period. The mode of glazing by common salt enabled the stoneware manufacturers to compete successfully with delft and soft-paste fabrics. Next, a very fine unglazed stoneware, with raised ornaments, known as "red Japan ware," was made in England, after the failure of many previous attempts. It appears that two brothers from Nuremberg discovered, near Burslem, a bed of fine red clay, which they worked at a small factory erected on the bed itself. They endeavoured to conceal their discovery and their mode of working, but the process soon became known. Their ware was fine in material and sharp in execution, the ornaments being formed in copper moulds.

ANIMAL COMMERCIAL PRODUCTS.—XV.

PRODUCTS OF THE SUB-KINGDOM ANNULOSA (*continued*).

As for nearly a year the queen bee does not lay any eggs destined to become queens, if any evil befall her during that time the hive is left without a queen. Her loss or death stops the work of the hive, and, unless another queen is provided, the bees either join another hive or perish from inanition. After about two days, however, the bees generally decide to provide themselves with a queen, and this state of anarchy subsides. A few of the workers repair to the cells in which their eggs are deposited, three of these cells are made into one, a single egg being allowed to remain in it. When this egg is hatched, the maggot is fed with a peculiar nutritive food, called "royal bee bread," which is only given to maggots destined to produce queens. Work is now resumed over the whole hive, and goes on as briskly as before; on the sixteenth day the egg produces a queen, whose appearance is hailed with delight, and who at once assumes sovereignty over the hive.

If the old queen should survive, and the young queens emerge from the eggs last deposited by the old queen under ordinary circumstances, the workers do not allow them instant liberty, as severe battles would take place between them and the reigning queen; they are therefore kept prisoners in the cell, and fed through a small hole which is made in the ceiling of their cell, through which these captive queens thrust their tongues and receive their food from the workers. In this state of confinement the young queen bee utters a low complaining note,

which has been compared to singing. When the old queen finds one of these captives, she uses every effort to tear open the cell and destroy her rival; the workers prevent this, pulling her away by the legs and wings. After repeated attempts to penetrate the cells and destroy her royal progeny, the old queen becomes infuriated, communicates her agitation to a portion of her subjects, who, together with her, rush out of the hive and seek a new home. The queen and accompanying swarm generally fly to some neighbouring resting-place, are observed by the owner, captured, placed in a new hive, and a new colony is at once commenced. The labourers that remain pay particular attention to the young imprisoned queens, and these, as they are freed from confinement, successively lead off fresh swarms, if the hive be not enlarged. Each swarm contains not only the recently-hatched young bees, but also a portion of the old inhabitants. After the hive has sent off three or four swarms, there are not enough bees left to guard the royal cells. The young queens consequently escape, two or three at a time; a battle ensues amongst them, and the strongest remains queen of the hive, after destroying all the royal larvæ and pupæ that remain.

According to Huber there are two varieties of working bees. The nurse-bees, which continue in the hive, whose office is to build the comb and feed the larvæ; and the collecting bees, which fly abroad and bring back to the hive the pollen and honey which they collect. This pollen is formed into little pellets, and packed on the hind legs in the receptacle formed there for this object. Honey is also swallowed by the bee, which passes into the crop, where it accumulates as in a reservoir, and on the return of the bee to the hive is poured into a honey cell. When a pollen-laden bee arrives at the hive, she puts her two hind legs into a cell, and brushes off the pellets with the intermediate pair. These pellets are kneaded into a paste at the bottom of the cell. The softened kneaded pollen thus packed away is called "bee-bread." Besides honey and pollen, bees collect a gum-resin called by Pliny *propolis*, principally from the balsamic buds of the horse-chestnut, birch, and poplar. This is used in closing up crevices in their hives, and in strengthening the margins of the cells of the comb.

Honey and *Wax* are two valuable commercial articles for which we are indebted to the labours of the hive bee. Bees'-wax is prepared by melting the comb in boiling water after the honey has been removed; the melted wax is then strained and cast into cakes, which have a pale-yellow colour and a pleasant odour.

White bees'-wax is formed by exposing the yellow wax in thin slices or ribands to light, air, and moisture, and then re-melting and forming it into cakes. Wax candles are made by suspending the wicks upon a hoop over a caldron of melted wax, which is successively poured over them from a ladle till they have acquired the proper size, so that the candle consists of a series of layers of wax; the upper end is then shaped and the lower cut off. Wax is also much used in taking casts or moulds, and as an ingredient in cerates and ointments. It is of great value in anatomy in representing normal or diseased structures. Most of our anatomical museums have instructive preparations made of this substance.

In addition to the large amount of wax, the annual produce of our own hives, considerable quantities are received from Canada. Africa also sends us heavy supplies. About 300,000 lb. are annually shipped from Madras. Altogether we use every year in this country about 500 tons of wax, valued at £200,000. Above 2,000,000 lb. of honey are annually imported into the United Kingdom, in addition to that obtained from our own bee-hives.

THE COCHINEAL INSECT (COCCUS CACTI).

Cochineal (*Coccus cacti*).—This valuable insect was first introduced into Europe in 1523 from Mexico. It belongs to the order *Hemiptera*, or half-winged insects.

The culture of the cochineal insect has extended from the New to the Old World, and it is now produced in India, Java, Algiers, and many parts of Europe. The cochineal insect is small, rugose, and of a deep mulberry colour. It feeds on several species of cacti. These insects are scraped from the plants into bags, killed by boiling water, and then dried in the sun. Those are preferred which are plump, of a silvery appearance, and which yield when rubbed to powder a brilliant crimson. It is estimated that 70,000 of these minute insects are necessary to make a single pound of cochineal. In 1868 we imported 35,375 cwt. of cochineal, valued at £588,691.

The red colouring matters known by the names of *carmine* and *lake* are made from cochineal. Cochineal is used for dyeing scarlet, and is employed chiefly for woollen goods. The dye is obtained by fixing the colouring matter of the insect by a mordant of alumina and oxide of tin, and exalting the colour by the action of super-tartrate of potash.

THE ELECTRIC TELEGRAPH.—VI.

By J. M. Wigner, B.A.

CONSTRUCTION OF SINGLE-NEEDLE INSTRUMENTS — THE COMMUTATOR — THE COIL — SWITCHES — SWISS COMMUTATOR—MODE OF JOINING UP CIRCUIT.

Besides the regular signals we have already enumerated, there are always a few others to denote various special things; but, as these do not form part of the universal code, and are occasionally varied, we need not insert them here, but may pass on at once to explain in detail the mechanism of the instrument itself.

This will easily be understood by reference to Fig. 23, which represents a back view of the interior of a single-needle telegraph instrument, the outer case being entirely removed. No alarum is shown here, that being frequently contained in a separate case; sometimes, however, for the sake of convenience, it is placed in the upper portion of the instrument-case, and even then it is quite distinct from the rest of it.

At the back of the base-board are seen four binding-screws, by which the instrument is joined in circuit with the batteries and the line. The wires leading from the positive and negative terminals of the battery are connected with two of these, marked respectively C and Z. The terminal L is connected with the line-wire, and E with the earth-plate.

The handle seen on the face of the instrument is securely fastened to the cylinder, *a b*, of the commutator. This is made of some hard, dry wood, usually box, and is supported in front by the dial-plate, through which its axis passes, and at the back by the support D. In the figure it is shown in the position it occupies when the handle is pressed to the right, so as to send a beat in that direction. The barrel, or cylinder, has a metal ring at each end (*a* and *b*); these are perfectly insulated from one another by the dry wood between them. A brass spring, *c*, presses against the front one of these rings, and thus this end of the cylinder is in constant connection with the binding-screw Z, through the medium of this spring and the brass strip leading from it.

Fig. 24.

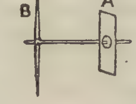
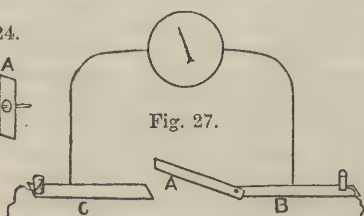


Fig. 27.



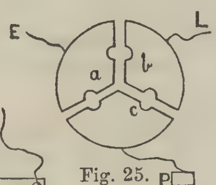


Fig. 25.

Fig. 26.

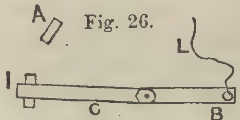


Fig. 28.

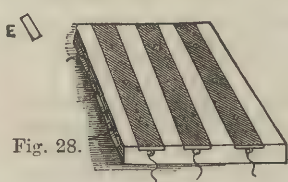
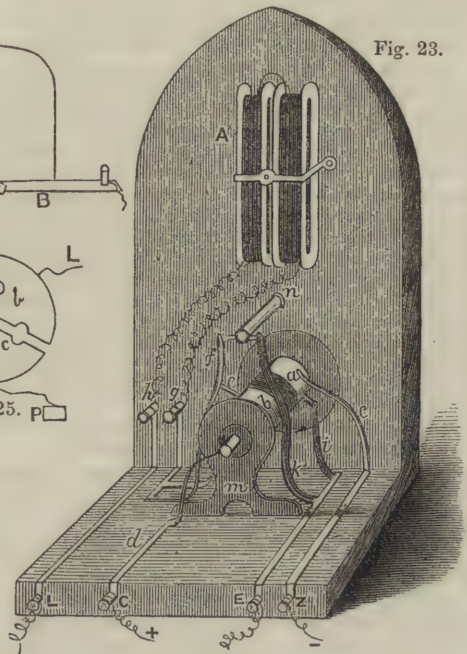


Fig. 23.



The other end of the cylinder is in metallic communication with the axle at that end of the cylinder, and thus, through the medium of the strip *d* and the spring which rises from it, with the binding-screw C. It will thus be seen that, by means of these springs, the two ends of the cylinder become virtually the two poles of the battery.

Two short pegs of stout wire are inserted in the metal rings of the cylinder—one in the under side of the front ring, and the other on the upper side of the back ring. These are so placed as to be in the same plane as the handle in front.

From E a strip of brass passes along the base, parallel with the cylinder, and is connected to a brass spring, *k*, so arranged that when the cylinder is inclined in that direction the pin *e* shall come in contact with the spring and raise it. A stout piece of brass, *i*, is likewise connected with the strip, and this serves as a stop for the pin in *a* to strike against.

On the other side of the instrument is a similar spring, *f*, and stop, but these are connected with the binding-screw *g*. The springs *k* and *f*, when not raised by the pin *e*, rest against the ends of a short piece of brass fastened to the support *n*, and thus are in metallic communication with one another.

This, then, is the transmitting part of the apparatus, and above the commutator is seen the coil A, which is essentially the receiving portion. In its construction this is very similar to the "detector" referred to in page 255, being merely a delicate galvanometer, with the needle placed vertically. Two small cases are made of thin wood or pasteboard, allowing just sufficient room for the needle to swing freely within them. They are then carefully wound round with very fine copper wire covered with silk, so as to insulate the successive layers. Considerable care is required in winding these coils, as if the wires in the different layers run at all crosswise much of the power is lost. Both coils are wound in the same direction, and the ends are then connected, so as to make one continuous circuit round both.

The reason for having two separate coils is that it renders it much more easy to put the needle in its place, one end of the axis being supported in the bearing seen behind the coils, while the other turns in a small hole in the bridge seen on the dial face. The construction of the needle is shown in Fig. 24, where A is the magnetised needle which is within the coil, and B that seen on the face of the instrument. The latter is usually unmagnetised, and serves merely as a pointer. In some instruments, however, both are magnetised, the poles being reversed so as to render the combination astatic. In either case the lower end is slightly weighted, so as to cause the needle to resume its vertical position immediately the current is interrupted. The needles are held in their places by means of small nuts on each side of them, screws being cut on the axis at the places where they are.

The ends of the coil are connected to the binding screws *g* and *h*, the latter being in communication with L by means of a brass strip.

We are now in a position to trace the course of the current through the instrument, and in doing so shall understand clearly the purpose served by the different springs and strips of which we have been speaking. First of all, we will suppose that a distant station is sending a message. In this case the batteries of the receiving station are not required, the only thing necessary being a direct path by which the current, as it arrives, may pass round the coils and on to the earth-plate. This we shall see is the case when the handle is vertical.

The current arrives by the line-wire, and reaches L; it then travels along the strip to *h*, traverses the coil, returning to *g*; from this it passes up the strip *f*, across the piece of wire against which this rests to *k*, and thence to E and the earth-plate. In this way the line-wire and the earth-plate are virtually connected directly to the ends of the coil, and for a simple receiving apparatus this is all that we need.

Now let us trace the course of the current when we send a message. Let us imagine the handle to be turned to the right, as shown in the illustration. The pin *e* first of all raises the

spring f off the support against which it leans, the other pin then comes in contact with i. The current now passes from C, along d, to the axis of the commutator, thence, by e and f, to the screw g. It then passes round the coils, and returns to h, whence it goes from L along the line-wire, round the coil of the instrument at the further end, and back, by the earth, to E. The circuit is then completed by the stop i, the cylinder a, and the spring c.

When the cylinder is turned in the other direction, the course of the current is from C, by d, e, k, to the earth-plate, returning from L, by h, g, a, and c, to Z, so that now it passes round the coil in the reverse direction, and accordingly deflects the needle to the left instead of to the right.

When the instrument is not a terminal one, but in the middle of a circuit, L is usually connected with the line-wire on one side, and E on the other. A switch is, however, connected with the instrument, so that earth may be put on at either side at pleasure, and the instrument on that side is thus cut altogether out of the circuit.

Many different forms of switches are often employed for purposes similar to the above, and it is well, therefore, just to explain the principle on which they act. In Fig. 25 we have a figure of an ordinary peg switch, suitable for the case referred to. Three plates of brass are fixed upon a board in the manner there shown. One of these is placed in connection with the earth-plate, the other two with L and E respectively. If, then, we want to receive a message from L, we can cut off all stations on the other side by inserting a brass peg in the opening a, which will make a direct communication between E and the earth-plate. In a similar way we can cut off the stations on the other side by inserting the peg in c; while if it be necessary at any time to cut our own instrument altogether out of circuit, without interfering with other stations on the same line, we can easily do so by inserting the peg in b. In each case a much shorter path is provided for the current, and as it always travels along that which offers least resistance, it takes this in preference to the route through the instrument. When any instrument is by any such contrivance cut off from the rest, it is said to be "short circuited," and an arrangement of this kind is very frequently employed.

It not unfrequently happens that there are several different circuits between which communications are at times required to be made, and in this case the number or shape of the brass plates is altered so as to meet the special circumstances.

Another contrivance frequently employed for the same purpose is known as the "lever-switch," and will be understood from Fig. 26. The line-wire is connected to a binding-screw on a strip of brass, B. A second strip, C, turns on a pivot at the end of this, and can at pleasure be made to rest on the springs or studs, A, I, and E, which are connected respectively with the alarum, the instrument, and the earth-plate, or any other pieces of apparatus. The current may therefore be made to take either of these courses as may be desired, and the number of pegs may be increased if needed.

This switch is not so much employed as the peg-switch already described, since the number of combinations that can be effected by means of it is much more limited; it is, however, simple in construction, and less liable to be left wrong by accident.

In Fig. 27 we have a diagram showing the simplest form of short circuit that we can employ. The two wires are brought to binding-screws affixed to the brass strips B and C, and from these other wires lead to the instrument. Another strip of brass is attached by a pivot to B, so that when it rests on C a direct passage is provided for the current from B to C, but when in the position shown the current must pass through the instrument.

When there are several instruments in an office, and several different lines of telegraph starting from it, various arrangements of this kind are almost indispensable. Very frequently the different wires are brought to one part of the building, and connected there to a series of binding-screws, each of which is distinctly labelled.

When there are several different circuits, which have at times to be connected, the "Swiss Commutator," or "Universal Switch," represented in Fig. 28, is found a very useful contrivance. A flat slab of some hard, dry wood is taken, and strips of brass are inlaid on each side of it, those on the upper side running in the reverse direction to those on the lower. Holes are then drilled through these strips, as shown, and by inserting a spring brass peg in the proper one of these, a communication may be established between any one of the upper and any one of the lower circuits.

Many other contrivances of this nature are often employed, but we need not stop to refer to them in detail.

In our next lesson we shall describe a simpler form of commutator that is now adopted on many lines; but it will be best first to explain the method of joining up any circuit, that is, of making the proper connections with the batteries and line-wires. We will suppose that we have two stations with instruments, batteries, and line-wires all complete, and we want to establish the communication between them.

First of all, let each clerk connect the binding-screws L and E of his own instrument by means of a loop of wire, unless, as is frequently the case, there is an arrangement in the instrument for doing this by a short circuit. The battery wires are now connected to C and Z respectively; sometimes there is a difficulty in determining which is the proper wire for each screw, but this is easily obviated. We have merely to connect one wire to each screw, and then turn the handle in front of the instrument. If the connections are rightly made, the needle will move in the same direction as the handle is inclined. Should it move in the contrary direction, we at once know the wires are wrong, and have simply to reverse them.

The loop of wire is now taken off, and the line and earth wires joined on; the operator at the other end then sends a few deflections to the right, and we at once see if the wires have been rightly connected, and if they have not we reverse them. In this way all the connections are sure to be right; the main point to remember is that we first of all make sure our own batteries are rightly connected, and then afterwards see to the line-wires. Bearing this in mind will frequently save considerable trouble and loss of time.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

IX.—GEORGE STEPHENSON.

BY JAMES GRANT.

GEORGE STEPHENSON, the engineer (father of the constructor of those vast works, the High Level Bridge across the Tyne, the Britannia Tubular Bridge, and that mightier work of art, the bridge across the St. Lawrence), was the second son of Robert Stephenson and his wife Mabel, and was born on the 9th of June, 1781, in a humble clay-floored cottage in the colliery village of Wylam, eight miles from Newcastle. There were five other children, whose lot was the heritage of toil, and all had to toil hard, for the wages of their father were small, as his occupation was that of fireman to a coal-pit engine. George was in his eighth year when his father was employed in a colliery at Dewley Burn, where the situation of a herd-boy enabled him to earn twopence per diem to aid the half-starved family. From being a herd, the boy was promoted to lead horses when ploughing, to hoe turnips, and do other farm work, which raised his earnings to fourpence daily; yet his taste lay not in agriculture, but among those grimy pits where he had first seen the light, and he obtained employment as a gin-horse driver at the colliery of Black Callerton, two miles distant from his father's cottage, and in his fourteenth year he thought that he had attained the height of his ambition, when he earned a shilling per day as assistant fireman to his father at Dewley Burn. On this pit being worked out, the workmen and apparatus were removed to another at Jolly's Close, and thither went the Stephensons, to become the occupants of a cottage composed of one apartment, in a humble street of similar dwellings, with mountains of slag behind, and a run of foul water in front. The total earnings of the whole family amounted to nearly £100 per annum; they lived rent-free, and yet not a penny was ever spent on education or mental culture of any kind; for the social ideas of the Northumbrian colliers were then low indeed. "Let any one picture to himself the situation of a friendless lad totally uneducated, living in such a colliery village, and then try to conceive by what force of circumstances that lad was to attain eminence in wealth and station and as a benefactor to mankind!"

At the colliery of Throckley Bridge he was employed in attending to the furnace of one of the giant engines which cleared the pit of water, and then his wages were twelve shillings weekly, and there the lad seemed to be in his peculiar element; he would scour and grease, polish and work among wheels and levers, pistons, pumps and cylinders, till he actually came to regard his engine with something akin to admiration and affection. It became a kind of hobby with him to take *her*—for so he called it—to pieces, examine all the component parts, clean, and put them together again; then a shout of pleasure would sometimes escape him when the steam was let on—when the great lever went down and brought up a volume of water that flowed away like a small river; but his eighteenth year found him still ignorant of the alphabet!

The necessity for education began to impress him seriously now; he could model miniature engines in clay, thus fixing the shapes and proportions in his memory; but when he was told of others that he had never seen but could read of in books, he resolved that, cost what it might, he would go to school; and after a few preliminary lessons, received from a poor teacher, named Robin Cowens, at the rate of threepence weekly, he began regularly to attend an evening school, kept by Andrew Robertson, a Scottish dominie in the village of Newburn, where he rapidly advanced in penmanship and arithmetic. The latter he studied with a slate while attending to the engine, thus utilising time; and this was all the education he ever received.

The year 1801 found him a workman at the Dolly-pit of Callerton; but though wages were high, food was scarce and dear; thus he was compelled to spend his evenings, not in study, but in making and mending shoes. In this branch of trade he became an expert cobbler, and "if anything could have spurred him on, it was the desire to sole the shoes of his sweetheart, pretty Fanny Henderson, and of these he is said to have made a capital job." He studiously avoided all taverns or public-houses, and his sobriety, industry, and energy had ere long their reward. His savings enabled him to furnish a small house at Willington Ballast Quay, on the Tyne; and there he brought home Fanny as his wife on the 28th of November, 1802.

From mending shoes, he now betook him to the repair of timepieces, and was known among his neighbours by the *sobriquet* of "the clock-doctor." On the 16th of December, 1803, was born his only son, Robert, who lived to attain the head of his profession as a railway engineer. In the following year he lost his young wife, to whom he was deeply attached, and the blow was all the heavier that his son was still an infant. He was then employed as a brakesman of the coal-lifting machinery at Killingworth, where he won the reputation of being a skilful and trustworthy workman.

Being invited to superintend an engine near Montrose, in Scotland, he left his child in charge of a neighbour's wife, and set out for the scene of his new employment, two hundred miles distant. This journey he performed on foot, carrying a wallet; but after some quarrelling with his Scotch employers, he left them, to trudge back in the same humble fashion—his total earnings being £28, which enabled him to succour his father, who was then aged and blind, and whom, with his old mother, he contrived to place in a comfortable cottage near Newcastle.

The year 1807 saw him drawn as a private of militia, and every shilling he had saved was spent in procuring a substitute; a loss which exasperated him so much, that for a time he conceived the idea of emigrating to America. Amid all his struggles and pecuniary difficulties at this dark period of his life, it is to his honour that he never failed in providing for the wants of his aged parents, and for his child that education, of which he had so sorely felt the loss himself. Three years after his escaping the militia ballot, there occurred an opportunity for bringing his name prominently forward in his own locality.

At Killingworth High Pit there was a badly-constructed steam-engine, which failed to do its work. Several engineers in succession had failed to put it right, and the proprietors were glad to let George Stephenson examine it. Though he had a great reputation for cleverness—nothing more—they never expected him to succeed. He took the entire engine to pieces, re-arranged it, and set it to work in the most effectual manner, to the mortification of those who had miscarried, and the satisfaction of the proprietors, who presented him with a gratuity of £10. This event placed him on the footing of a regular engineer, and as such he was consulted in all cases of defective pumping apparatus. The year 1812 saw him engaged in planning machinery for working pits and wheeling off coal; and the collieries of Mountmoor, Killingworth, Derwentcrook, South Moor, and others belonging to Lord Ravensworth and his partners, were all put under his care.

Among those who had thought deeply for years of the proper application of steam to carriages was Stephenson, who, after many experiments, began to run a locomotive on the Killingworth Railway in July, 1814. This he named the "Blucher," in honour of the Prussian marshal. At best it was only a coal-drag, that drew eight wagons of thirty tons at the rate of four miles an hour. It was full of defects, and clumsy; but Stephenson soon remedied all by giving the furnace more draught; he sent the waste steam into the funnel, by which the power of the engine was doubled, and ere long tripled. In the following year, having had his attention drawn to the disasters in mines by the explosion of fire-damp, he devised a safety-lamp, not unlike that invented about the same time by Sir Humphry Davy.

Still planning improvements at Killingworth, Stephenson continued to develop travelling by steam, and step by step the rail and the engine were brought to a comparatively perfect state, and he was enabled to send his son to study at the University of Edinburgh. The engineering of the Stockton and Darlington Railway was assigned him, and it became, in most respects, the model for general railway work. He was already a partner in a locomotive manufactory at Newcastle, and three of these were ordered by the new Company, whom Parliament had empowered to employ steam in the conveyance of passengers and goods, in lieu of the old horse-tramways.

The 27th of September, 1825, saw the opening of this, the first public railway; when, at a given signal, the engine started, at the rate of twelve miles an hour, with 450 passengers, and ninety tons of coals and merchandise, and reached Darlington, a distance of 8¾ miles, in 65 minutes. When the Manchester and Liverpool Railway was before Parliament in the same year, Stephenson, in the face of strong opposition from interested antagonists, gave much valuable information respecting the practicability and safety of trains drawn by locomotives, though, as yet, he had no idea of a speed that exceeded twenty miles an hour; but even this was so greatly doubted, that one of the members of the committee remarked, that "the engineer who conceived such ideas was only fit for a lunatic asylum!" Opposition crushed, and legal sanction given, the railway company set to work, and, with a salary of £1,000 per annum, Stephenson was appointed their engineer, with instructions that the line between Manchester and Liverpool was to be kept as straight as possible. In this great undertaking, the first novel series of engineering had to be undergone—viaducts were to be built, hills tunnelled, embankments formed from the *débris* of cuttings, and the four miles of dreary bog known as Chat Moss converted in a hard and firm way ere the line was completed; and £500 was offered for the best locomotive that could be brought forward for competition in running by a certain day. Stephenson determined to compete; and on the 8th of October, 1829, three engines were brought forward; the "Rocket," by him, and two others by Hackworth and Messrs. Braithwaite and Ericson. The test assigned was to run a distance of thirty miles, at not less than ten miles per hour, along a two-mile level near Rainhill, with a load thrice the weight of the engine. One locomotive was disabled by the failure of the boiler-plates; another attained fifteen miles an hour, but failed to accomplish the distance; and the "Rocket" alone stood the test and won the prize, attaining a maximum speed of twenty-nine miles an hour. This day was somewhat of an epoch in engineering, as coke was burned instead of coal, and the coke and water were carried in a tender attached to the engine.

On September 15, 1830, the line was opened, and a train of eight locomotives and twenty-eight carriages, with 600 passengers, started amid the applause of thousands, who assembled from all quarters; but the day was not without a disaster. When at Parkfield, the train halted to replenish the water-tanks, and there Mr. Huskisson, M.P., was killed. Next day 130 passengers left Liverpool for Manchester, and by the close of the week six trains were running daily on the line, and the speed was soon increased to thirty-one miles in less than an hour. No less than thirty stage coaches were thrown out of employment, and their

500 passengers were increased to 1,600. This line now forms a part of the vast system known as the London and North-Western Railway.

Stephenson now occupied a high position indeed in the world of science. His skill was acknowledged; his perseverance rewarded. In 1837 he removed to Tapton Hall, near Chesterfield, and leaving his son Robert to perfect yet further the powers of the locomotive, when about sixty years of age he began to think of retiring from active professional life. But his career of usefulness was not yet over. He had to visit the Continent several times, to attend consultations on railways, and matters connected therewith; and on one of those occasions, together with his friend Mr. Sopwith, he had an interview with Leopold, King of the Belgians. He always figured prominently at the opening of railways, and at the festival of the Trent Valley Line, he was compared by Sir Robert Peel to Julius Agricola, the maker of the Roman roads in Britain.

"When I look back to the time when I *first* projected a locomotive in this neighbourhood," said he, in reply to Sir Robert's eulogium, "I cannot but feel astonished at the opinions which then prevailed. Even by the most celebrated engineers we were told that it would be impossible ever to establish railways. Judge, then, how proud must be the feelings of one who, foreseeing the *result* of railways, has risen from the lower ranks on their success!"

The High Level Bridge across the Tyne at Newcastle, the Conway and Britannia tubular bridges in North Wales, and the mighty tubular bridge, nearly two miles long, across the St. Lawrence, at Montreal, are lasting monuments of the vastness of his son's genius. Skilful subordinates assisted him, and it is but fair to admit that to the Scotchman, Sir William Fairbairn, of Manchester, is generally imputed the first idea of tubular bridge building. In 1844 Robert Stephenson was returned to Parliament as member for Whitby. Four years after this, his father died on the 12th of August, 1848, in his sixty-seventh year.

The close of his days was characteristic of the simplicity of his early life, for George Stephenson occupied himself with birds and dogs, and other domestic pets, and in rearing flowers and vegetables in his garden, which he worked with his own hands.

He was fond of visiting the scenes of his youth, among the smoky and grimy collieries of Newcastle; going to the places where of old he had worked as his father's assistant at the furnaces, and whom he had seen toiling, shovel in hand, clothed in worn woollen rags, and little foreseeing the future of his son or grandson "as he wiped the perspiration from his brow with a bunch of coarse tow."

It was remarked of George Stephenson, that though frequently invited to the houses of the great and wealthy, he never forgot his own humble origin, nor shrunk from recognising, or if possible befriending, an old fellow-workman. He gave advice cheerfully to all who required it of him in their career as engineers, but he had a peculiar aversion for all such as appeared to him overdressed, or indulging in airs or vanity.

"I hope you will excuse me, young man," said he one day to an applicant of this kind; "I am a very plain-spoken person, and I am sorry to see a nice-looking, and rather clever young man like you disfigured by that fine, but absurd waistcoat, and all those chains and fang-dangs. If I had troubled myself with such things when at your age, I should not have been where I am now."

Such was the chequered but brilliant career of George Stephenson.

His son survived him only eleven years. He died in 1859, in his fifty-sixth year, and was honoured with a public funeral and a grave in Westminster Abbey.

The life of George Stephenson is such as to afford encouragement to any man who seeks to get on in life, provided that he is possessed of sufficient earnestness of purpose and perseverance to proceed steadily towards the goal that he has in view. Filial love, economy, sobriety, and fixity of purpose were the cardinal points of the compass by which George Stephenson steered his course through life. To act as he did in the various relations and duties of life is within the power of all, and although the result obtained may not be so great, we may be sure that it will prove a rich reward for the efforts made to attain it.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—VI.

To construct a semi-elliptical arch, of which A B *is the span, and* C D *the height* (Fig. 56).

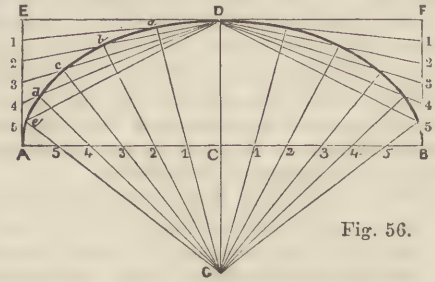


Fig. 56.

Divide C A and C B into any number of equal parts.

Divide A E and B F into a corresponding number of equal parts. Number the parts as in the figure.

Produce D C, and make C G equal to C D.

From D draw lines to the points 1, 2, 3, 4, 5, in the lines E A and F B.

From G draw lines through the points 1, 2, etc., in the line A B, and produce these lines until they cut those of corresponding numbers drawn from D to the points in the lines E A and F B.

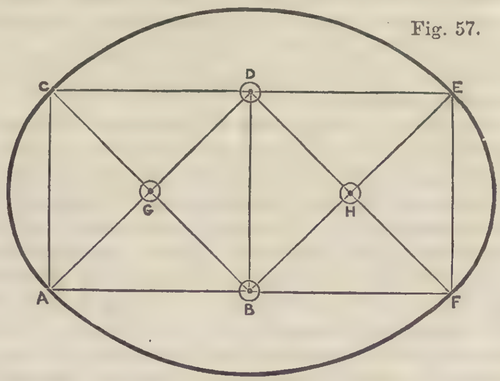
Thus—G 1	will cut	D 1	in *a*.
G 2	,,	D 2	in *b*.
G 3	,,	D 3	in *c*.
G 4	,,	D 4	in *d*.
G 5	,,	D 5	in *e*.

The curve is to be drawn through these intersections.

Strictly speaking, no portion of an ellipse is a part of a circle, and the curve cannot therefore be drawn with compasses so as to be mathematically correct; but there are many ways in which figures nearly approximating to ellipses may be drawn by arcs of circles; and among these the following is given:—

To construct an elliptical figure by means of two squares, A B D C, B D E F (Fig. 57).

Fig. 57.



Draw diagonals in each of the squares, intersecting each other in G and H.

From B, with radius B C, describe the arc C E.

From D, with the same radius, describe the arc A F.

From G, with radius G C, describe the arc C A.

From H, with the same radius, describe the arc E F, which will complete the figure.

THE SPIRAL.

The *spiral* is a curve, which makes one or more revolutions round a fixed point, but does not return to itself.

To construct a spiral of one revolution (Fig. 58).

Describe a circle, using the widest limit of the spiral as a radius, as A XII.

Divide the circle into any number of equal parts, as I to XII, and draw radii.

Divide one of these radii, as A XII, into a corresponding number of equal parts, as 1 to 12.

From the centre, with radius A 1, describe an arc cutting the radius I in B. From the centre, continue to describe arcs from points 2, 3, etc., cutting the corresponding radii II, III, etc., in the points C, D, E, F, G, H, I, J, K, L.

From XII trace a curve passing through all these points, which will be an Archimedes' spiral of one revolution

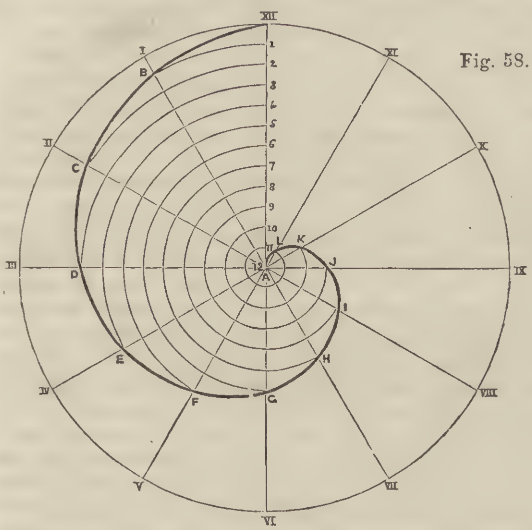


Fig. 58.

It will interest our students to learn that Archimedes, the most celebrated of ancient mathematicians, was born at Syracuse, B.C. 287. He cultivated particularly the branches of science relating to the areas of curves and sections of curved surfaces. He proved that the area of a circle is equal to half the rectangle contained by its circumference and radius, and showed how to approximate, as near as may be required, to the quadrature of a circle. The spiral was invented by Conon, but its properties having been demonstrated by Archimedes, it is in honour of him called by his name.

To describe a spiral of any number of revolutions—in this case three (Fig. 59).

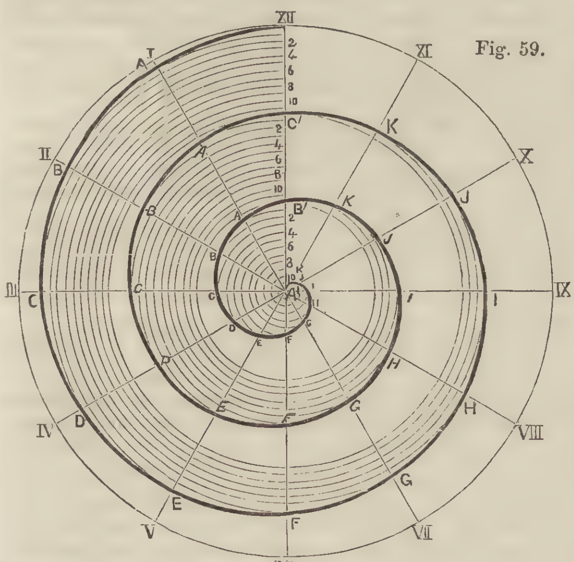


Fig. 59.

Divide the circle into any number of equal parts, as I to XII, and draw radii.

Divide one of the radii, as A XII, into a number of equal parts, A′ B′ C′, corresponding with the required number of revolutions.

Divide each of these into the same number of equal parts as there are radii—viz., 1 to 12.

It will be evident that the figure consists of three separate spirals—one from XII to C′, another from C′ to B′, and another from B′ to A′.

Commence, as in the former spiral of one revolution (Fig. 58), by drawing arcs from the points 1, 2, 3, etc., to the correspondingly numbered radii, thus obtaining the points marked with the largest capitals; and the first revolution having been brought up to C′, proceed in the same manner to draw arcs from the points 1, 2, 3, etc., contained between B′ and C′, cutting the corresponding radii in the points marked with the italic capitals, and draw the curve through these points, thus reaching B′.

Proceed in the same manner to draw arcs from the points between B′ and A′, thus obtaining the points marked with the smallest capitals, and the spiral may then be brought up to the centre.

To describe a spiral adapted for the volute of an Ionic column, by means of quadrants (Fig. 60).

Divide the given height into eight equal parts.

From 3 and 4, draw lines at right angles to A B.

Between these two lines describe a circle (the eye of the

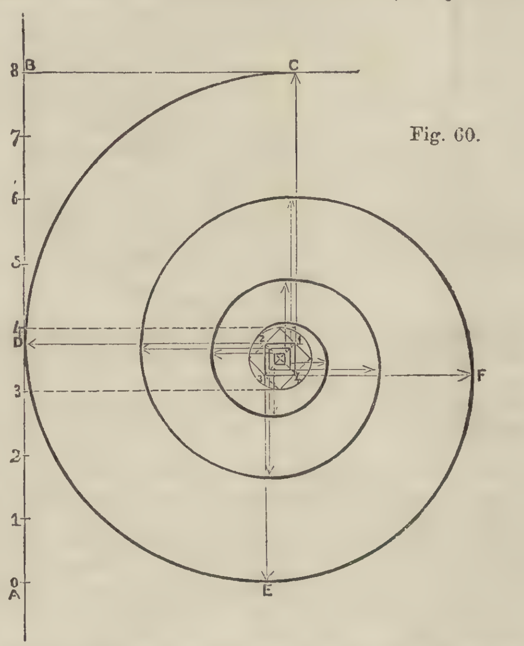


Fig. 60.

volute), the centre being at a distance from A B equal to four of the divisions. Inscribe a square in this circle. Bisect the sides of this square, join the bisecting points, and thus a smaller square will be inscribed in it.

Divide each of the semi-diagonals into three equal parts, join these points, and two more squares will be formed within the former one.

The quadrants are drawn in rotation from the angles of each square, commencing at 1 with radius 1 C.

The next is drawn from 2 with radius 2 D.
The next ,, 3 ,, 3 E.
The next ,, 4 ,, 4 F.

The process is then continued from the inner squares.

THE INVOLUTE (Fig. 61).

If a perfectly flexible line is supposed to be wound round any curve, so as to coincide with it, and kept stretched as it is gradually unwound, the end of, or any point in the line will describe or trace another curve, called the *involute* of the curve—being in reality the opening out, or *unrolling*, of the periphery of the first curved surface.

Thus, if a circular piece of wood were fastened on a board, and a string equal to the circumference fastened by one end to it and rolled round it, a pencil placed in a loop in the end of the string would, as the string is gradually unrolled, trace the involute.

The circle (or other original curve) is called the *evolute*.

To construct the involute of the circle A (Fig. 61).

Divide the circle into any number of equal parts (1 to 12), and draw radii.

Draw lines (tangents) at right angles to these radii.

On the tangent to radius No. 1, set off a space equal to one of the parts into which the circle is divided; and on each of the tangents set off the number of parts corresponding to the number of the radius. Tangent No. 12 will then be the circumference of the circle unrolled, and the curve drawn through the extremities of the other tangents will be the involute.

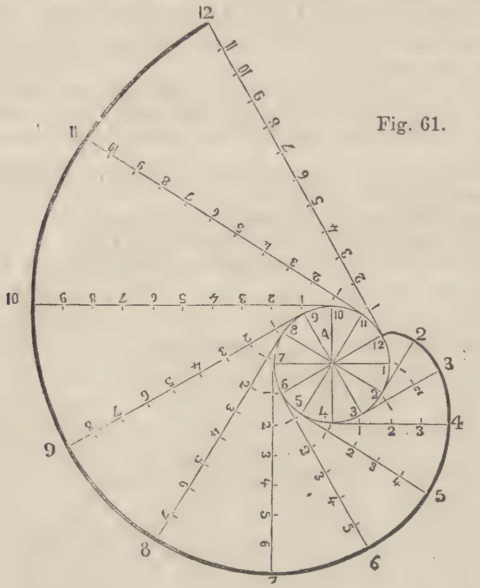
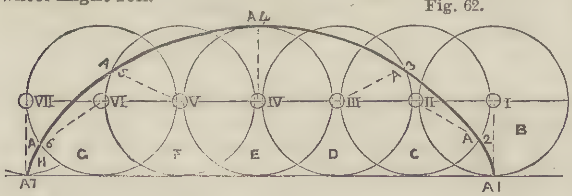


Fig. 61.

THE CYCLOID (Fig. 62).

If a mark were to be made with chalk on the iron tire of a wheel at the exact spot where it touches the ground, the white mark, as the wheel rolls along a level road, would be observed to move in a peculiar form, which is called the "cycloid" curve; whilst the centre of the nave of the wheel (I), although moving onward, would travel in a horizontal line, that is, it would keep exactly the same distance from the ground, however far the wheel might roll.

Fig. 62.



When the wheel is at B, its centre is at I, and the point A is at A 1.

When the wheel has moved to C, the centre will be at II, and the point A will be at A 2.

When the wheel has moved on to D, the centre will be at III, and the point A will be at A 3.

When the wheel has moved on to E, the centre will be at IV, and the point A will be directly over it, viz., at A 4.

When the wheel has moved on to F, the centre will be at V, and the point A will be at A 5.

When the wheel has moved to G, the centre will be at VI, and the point A will be at A 6.

When the wheel has moved on to H, the centre will be at VII, and the point A will be at A 7.

It will thus be clearly seen that the wheel in moving from A 1 to A 7 has passed completely through one revolution, and therefore that the length of the line A 1, A 7 is equal to the circumference of the circle laid out on a straight line.

The straight line on which the wheel rolls is called the *director*. The wheel is called the *generating circle*, and the point A is called the *generator*.

VEGETABLE COMMERCIAL PRODUCTS.—XII.

(*b*) VOLATILE OR ESSENTIAL OILS.

THESE oils occur in the stems, leaves, flowers, and fruits of most sweet-scented plants, whence they are obtained by distillation. In this respect they differ from the oils already described, which are found only in the seed, obtained by expression from the same, and do not evaporate; hence the latter have been called fixed oils. The difference between fixed and volatile oils is easily shown. A drop of any fixed oil—such as olive oil, for instance—leaves a stain on paper which is permanent; but a drop of any volatile or essential oil—as, for example, oil of bergamot—makes a similar stain, which evaporates and disappears.

To obtain essential oils, the leaves, flowers, or other parts of the plant are put into an apparatus for distillation. This always consists of a boiler in which the vapour is raised, and a condenser in which it again becomes fluid. For distillation on a small scale, a common retort and receiver answer every purpose, care being taken to keep the receiver cool, by placing it in cold water. When the water boils, the steam passes through the retort into the condenser, where it is re-converted into water, the essential oil floating on its surface; this is skimmed off, and afterwards purified by filtering. But the perfume of most flowers depends on the presence of a fragrant volatile or essential oil, peculiar to the plant. When, therefore, we obtain this oil, we really get the essence of the plant, or the essential principle which makes it valuable; and although the plant may be an annual, and perish, together with its fragrance, in a few weeks or months, yet, if we extract the oil, we can retain the essence of the plant as long as we please. The following are the most important of the essential oils which occur in commerce:—

OIL OF LAVENDER, from *Lavandula spicata*, L.; natural order, *Labiatæ*.—Large quantities are raised at Mitcham, in Surrey; but it is also imported from France and Germany.

OIL OF THYME, from *Thymus vulgaris*, L.; natural order, *Labiatæ*.—This oil is distilled from all parts of the plant. It comes into this country from Hamburg and from the United States. It is used in scenting Windsor soap.

OIL OF PEPPERMINT, from *Mentha piperita*, L.; natural order, *Labiatæ*.—Besides that raised and manufactured at home, we receive large quantities from Germany and the United States.

OIL OF ANISE, from *Pimpinella anisum*, L.; natural order, *Umbelliferæ*.—This plant is a native of the Levant, whence a great deal of the anise of commerce is derived. It is also much cultivated in France, Naples, and Germany—particularly in Thuringia and Swabia. We receive considerable importations from Germany and the East Indies; but those sorts coming from Spain, Apulia, and Malta, are considered in commerce to be the most valuable.

OIL OF CARAWAY, from *Carum carui*, L.; natural order, *Umbelliferæ*.—The best caraway oil comes from Malta, Naples, and Alicante in Spain. Small quantities are received from Germany. Much more, however, is home-manufactured and exported.

Cinnamon, clove, cassia, and pimento yield essential oils, to which reference has already been made in treating of those species; oil of bergamot, oil of lemons, and Neroli oil, or oil of orange flowers, have also been mentioned in connection with those fruits.

OIL OF ROSES, ATTAR OF ROSES, or OTTO OF ROSES, is distilled from the petals of *Rosa centifolia*, L., *Rosa gallica*, L., and numerous other species of rose. The attar of roses is prepared in Persia and other Asiatic countries; but, with all the aids of science, the process still remains unknown to Europeans. Some idea of its costliness may be gathered from the fact that 100,000 roses must be distilled to yield 180 grains, or three drachms of pure attar. Five guineas have often been paid for one ounce of this essence. It is the favourite perfume of the civilised world, and in the East is a most essential luxury. In Cashmere the harvest of rose leaves is celebrated as the festival of the year. Its description is well known in the exquisite poetry of Moore.

III. TINCTORIAL PLANTS, OR PLANTS FURNISHING VALUABLE DYES.

The clothing which is furnished by the textile plants and the sheep's wool would be of one dull uniform hue, if it were not for the valuable dyes furnished by the tinctorial plants. At first the colours of plants, when transferred to clothing, imparted

only a temporary beauty; for the art of fixing them, or uniting them permanently with the cloth, by means of mordants, was unknown; but by experiments long and carefully conducted, Nature has been interrogated successfully, and we are now able to render these colours fast, or permanent, thus enriching our silken, woollen, linen, and cotton manufactures with an almost endless variety of beautifully-coloured designs. It is impossible to mention even the names of the numerous plants which furnish materials for the dyer. Only a few, and those the most common in the commercial world, can be noticed. All the parts of plants furnish these dyes; sometimes it is the root, or the wood of the stem; sometimes the leaves, flower, or fruit.

Alkanet Root (*Anchusa tinctoria*, L.; natural order, *Boraginaceæ*).—A perennial herbaceous plant, with rough, oblong, lanceolate leaves, a stem about a foot in height, purplish flowers, and a long woody root, with a deep red bark. It is a native of the Levant, and is much cultivated in Germany and the south of France, particularly about Montpellier, for the sake of the red colouring matter contained in the bark of the root, easily obtained by soaking the root in alcohol or oil. It is used for colouring ointments red, especially lip-salves; it is also employed as a dye, to colour gun-stocks and furniture in imitation of rosewood. Alkanet root comes to this country in packages, weighing about two cwt. each, chiefly from Germany and France. About eight to ten tons are annually imported.

Sumach (*Rhus Coriaria*, L.; natural order, *Anacardiaceæ*).—The sumach of commerce is the crushed or ground leaves of this plant, imported from Sicily. This material is valuable for tanning light-coloured leather, and imparts a beautiful bright-coloured yellow dye to cottons, which is rendered permanent by proper mordants. In 1868 13,251 tons of sumach were imported into the United Kingdom.

Arnotto (*Bixa orellana*, L.; natural order, *Flacourtiaceæ*).—This is a small evergreen tree, indigenous to tropical America, and now cultivated in the East Indies. It is called *Roucon* by the French, and the Orleans tree by the Germans. The first South American settlers noticed the brilliant and showy colour obtained from its berries, on the bodies of the Indians, by whom it is called *bixa* or *bija*, and not only used it themselves, but speedily converted it into an article of commerce. The arnotto tree grows about twelve feet in height; its leaves are smooth and heart-shaped, and its pink-coloured flowers are followed by oblong bristled pods, somewhat resembling those of the chestnut, at first rose-coloured, but changing as they ripen to dark-brown. On bursting open, these pods show in their interior a splendid crimson farina or pulp, in which are contained ten or twelve seeds, in colour somewhat resembling coral beads. The arnotto of commerce is prepared from this crimson pulp. By maceration in hot water the seeds are separated from the pulp, which is then made into balls or cakes of two or three pounds' weight; these, when dry, are wrapped up in large leaves, and packed in casks for exportation. Another kind—the roll arnotto—is of a much superior quality. It is a hard extract, and contains a much greater proportion of colouring matter.

Good arnotto is of the colour of fire, bright within, soft to the touch, and dissolves entirely in water. It is used in Holland for colouring butter, and in Cheshire and Gloucestershire for dyeing cheese (under the name of cheese-colouring), to which it gives the required tinge, without imparting any unpleasant flavour or unwholesome quality. Flag or cake arnotto comes from the West Indies, especially from the island of St. Domingo or Hayti. Roll arnotto is principally brought from the Brazils. The rolls are small, not exceeding two or three ounces in weight. Arnotto is also used to dye silks and cottons, especially to form the colour called aurora. It is much to be regretted that the beautiful orange and gold-coloured dyes yielded by this plant are fugitive, and become discoloured in the sun. The bark of the arnotto tree makes good ropes, available in the West Indies for common plantation uses. The imports of roll and flag arnotto into the United Kingdom in 1863 were as follows:—Roll, 761 cwt., value £2,853; Flag, 2,507 cwt., value £10,111.

Myrobalans (*Terminalia chebula*, L.; natural order, *Combretaceæ*).—This dye is obtained from a small tree indigenous to British India, and closely allied to the myrtle. All the species of *Terminalia* have astringent properties. The fruit and galls of this tree are very astringent, and much valued both by dyers and tanners. The fruit is about the size of a date, pointed at the ends, and of a yellowish brown. The myrobalans of commerce are probably derived from more than one species. With alum they give a durable yellow colour. Myrobalans are now an important item in our commerce with India. We receive them from Calcutta and Bombay. The average annual imports are about 1,200 tons.

Safflower (*Carthamus tinctorius*, L.; natural order, *Compositæ*).—This plant furnishes a beautiful rose colour, which is used for silks, cottons, and the manufacture of rouge. Safflower is an annual herbaceous plant, somewhat resembling a thistle, to which it is allied. The leaves are ovate-lanceolate, somewhat spinous, alternate, sessile; flowers yellow.

The safflower is a native of the Levant, and is cultivated in China, India, and in the south of Europe. The dye is obtained from the florets. These are gathered, pressed into little cakes, dried, and then packed in strong bales, weighing about 2 cwt. each. As found in commerce, these cakes consist of flaky masses of a red colour, intermixed with yellow filaments, the former tint being due to the corolla, and the latter to the stamens. The flowers thus contain two colouring principles, one yellow, soluble in water, and the other rose-red, called carthamine, or carthamic acid, soluble in alkaline solutions; this latter, when precipitated from its solution, dried, and mixed with finely powdered talc, constitutes rouge. It is the carthamic acid which renders the safflower valuable as a dye. The greater portion of the safflower imported into England comes from Persia, Egypt, and the East Indies. The imports in 1851 were nearly 600 tons.

Logwood (*Hæmatoxylon Campeachianum*, L.; natural order, *Leguminosæ*).—A middle-sized tree with a contorted trunk, rarely more than one foot and a half in diameter, covered with ash-coloured bark; branches crooked, beset with sharp thorns; leaves pinnate or somewhat bi-pinnate, with sub-cordate leaflets; flowers yellow, in terminal racemes.

This tree, indigenous to Central America, Mexico, and Campeachy, has been introduced into the West Indies, and is now naturalised there. The heart-wood is the part of the tree employed; the generic name refers to its blood-red colour. Logwood is of very frequent use in the arts, as it forms the basis of many of the reds in printing calicoes, and is esteemed one of the best deep-red dyes. It is imported in logs, which are cut up into chips and ground to powder, for the use of dyers, hatters, and printers, in powerful mills constructed for that purpose. Logwood, when boiled, communicates its own dark-red colour to the water, and the addition of a few drops of acetic acid changes the colour to a bright red. Red ink is made in this way, a little alum being added to render the colour permanent. If, instead of an acid, an alkali—such as soda or potash—be added, the colour changes to a dark blue or purple, and with a little management every shade of these colours may be obtained. Logwood is so hard and heavy as to sink in water. It is used chiefly for dyeing red, blue, and black. We import every year about 40,000 tons from South America, whence a great deal also goes to Spain, France, and Germany. The principal ports for the reception of logwood are London, Cadiz, Bordeaux, and Hamburg.

Madder (*Rubia tinctoria*, L.; natural order, *Rubiaceæ*).—A small, herbaceous, perennial creeping plant; stems slender, quadrangular; leaves four in a whorl; flowers small; fruit yellow; berry double, one being abortive.

Madder is cultivated in France, Southern Europe, and the Levant, where it is indigenous, for the sake of the valuable red dye furnished by the root. The roots are dug up when the plant is about three years old, carefully dried, and packed into bags or bales for exportation. As found in commerce, madder-root is in long cylindrical pieces, about the thickness of a quill, and of a deep red or brown colour. If ground before exportation, the powder is sent in very large casks. We get madder roots whole from India, Turkey, Greece, Spain, and France; and ground from Holland and Germany. Powdered madder root is a bright Turkey red, but, by the addition of suitable chemicals, every shade of red, purplish-brown, purple, lilac, and even a lively rose colour can be obtained from it. Madder root imparts its red colour to water and alcohol. It is used as a basis for red dyes, as it affords a tint which, when properly fixed by appropriate mordants, is not affected by light or moisture. Scarcely a calico or muslin print is made without the aid of madder root, in some way or other, for forming the pattern.

The imports of madder root into the United Kingdom in 1868 were 177,336 cwt.; of madder, 128,242 cwt.

PRINCIPLES OF DESIGN.—X.

ART FURNITURE (*continued*).

By Christopher Dresser, Ph.D., F.L.S., etc.

In my last chapter I gave, in an axiomatic form, those principles which should guide us in the construction of works of furniture, and there endeavoured to impress the necessity of using wood in that manner which is most natural—that is, "working" it with the grain (the manner in which we can most easily work it), and in that way which shall secure the greatest amount of strength with the least expenditure of material. I again invite my readers to consider these matters, for they lie at the very root of the successful construction of furniture. If the legs of chairs, or their seat-frames, or the ends or backs of couches, are formed of wood cut across the grain, they must either be thick and clumsy, or weak; but, besides this, the rightly constituted mind can only receive pleasure from the contemplation of works which are wisely formed. Daily contact with ill-shaped objects may have more or less deadened our senses, so that we are not so readily offended by deformity and error as we might be; yet, happily for us, directly we seek to separate truth from error, the beautiful from the deformed, reason assists the judgment, and we soon learn to feel when we are in the presence of the beautiful or in contact with the degraded.

My illustrations, given some in this chapter and some in the last, in page 313, will show how I think chairs should be constructed. Fig. 19 is essentially bad, although it has traditional sanction, hence I pass it over without further comment. Fig. 23 is in the manner of an Egyptian chair. It serves to show the careful way in which the Egyptians constructed their works. The curved rails against which the back would rest are the only parts which are not thoroughly correct and satisfactory in a wood structure. Were the curved back members metal, the curvature would be desirable and legitimate. The back of this chair has immense strength (the backs of some of *our* chairs are of the very weakest), and as a whole it is a seat which would, if well made, endure for centuries. Fig. 20 is a chair of my own designing, in which I have sought to give strength to the back by connecting its upper portion with a strong cross-rail of the frame.

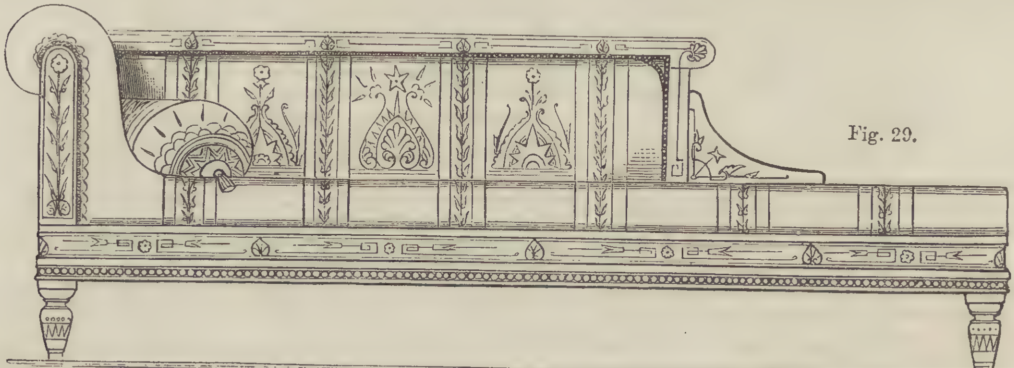


Fig. 29.

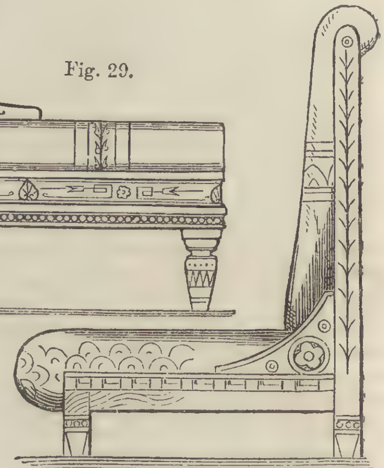


Fig. 26.

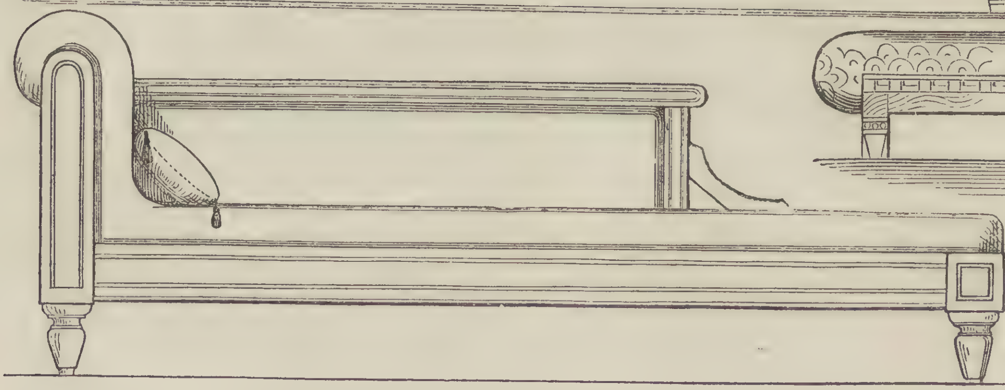


Fig. 30.

Fig. 21 is a chair slightly altered from one in Mr. Eastlake's work on "Household Furniture;" as shown in our illustration, it is a correctly formed work. Fig. 22 is an arm-chair in the Greek style, which I have designed. Fig. 26 is a lady's chair in the Gothic style. Fig. 25, a lady's chair in early Greek. These I have prepared to show different modes of structure; if the legs are fitted to a frame (the seat-frame), as in the early Greek chair just alluded to, they should be very short, as in this instance, or they must be connected by a frame below the seat, as in Fig. 27. The best general structure is that in which the front legs pass to the level of the upper surface of the seat.

Fig. 27 is a copy of a chair shown by Messrs. Gillow and Co., of Oxford Street, in the last Paris International Exhibition. In many respects it is admirably constructed. The skeleton brackets holding the back to the seat are a very desirable adjunct to light chairs; so are the brackets connecting the legs with the seat-frame, which strengthen the entire chair. The manner in which the upper rail of the back passes through the side uprights and is "pinned" is good. The chief, and only important, fault in this chair is the bending of the back legs, involving their being cut against the grain of the wood.

Fig. 28 is a chair from Mr. Talbert's very excellent work on "Gothic Furniture." It shows an admirable method of supporting the back. Fig. 24 I have designed as a high-backed lounging chair. With the view of giving strength to the back, I have extended the seat, and arranged a support from this extension to the upper back-rail, and this extension of the seat I have supported by a fifth leg. There is no reason whatever why a chair should have four legs. If three would be better, or five, or any other number, let us use what would be best. In my drawing, the stuffing of the back has been accidentally shown somewhat too rounded. This does not in any way interfere, however, with what I have in view—viz., the illustration of a particular structure or formation of chair.

I have now given several illustrations of modes of forming chairs. I might have given many more, but it is not my duty to try and exhaust a subject. What I have to do is simply to point out principles, and call attention to facts. It is the reader who must think for himself—first, of the principles and facts which I adduce; secondly, of the illustrations which I give; thirdly, of other works which he may meet with; and fourthly, of

further means of producing desirable and satisfactory results than those set forth in my illustrations.

As it cannot be doubted that a well-constructed work, however plain or simple it may be, gives satisfaction to those who behold it—while a work of the most elaborate character fails to satisfy if badly constructed—we shall give a few further illustrations of structure for other articles of furniture besides chairs, which have become necessary to our mode of life.

lateral pressure, but would not bear quite the same amount of pressure from above. The latter, however, could bear more weight than would ever be required of it, and would be the more durable piece of furniture.

Fig. 31 gives a legitimate formation for a settee; the cutting-out, or hollowing, of the sides of the legs is not carried to an extreme, but leaves a sufficiency of strong wood with an upright grain to resist all the pressure that would be placed on the

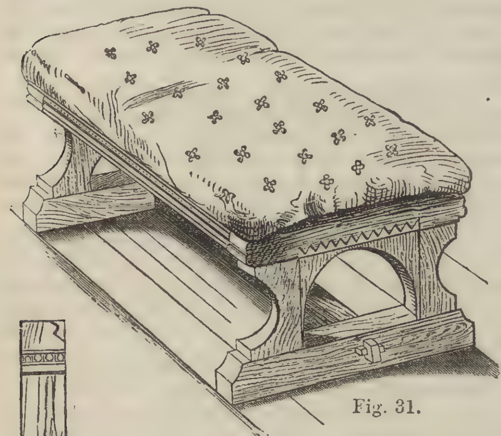


Fig. 31.

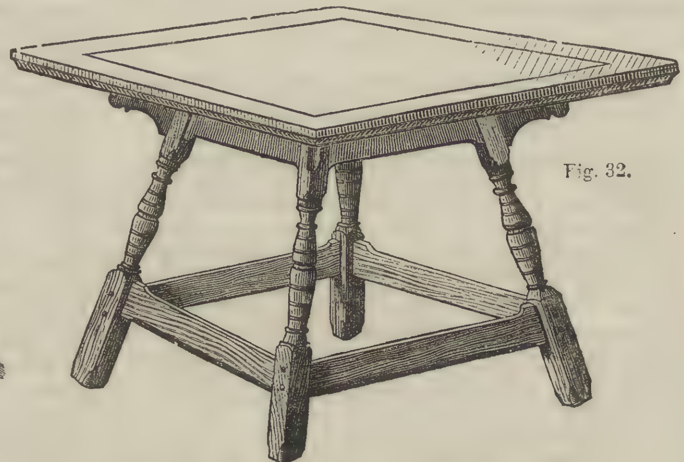


Fig. 32.

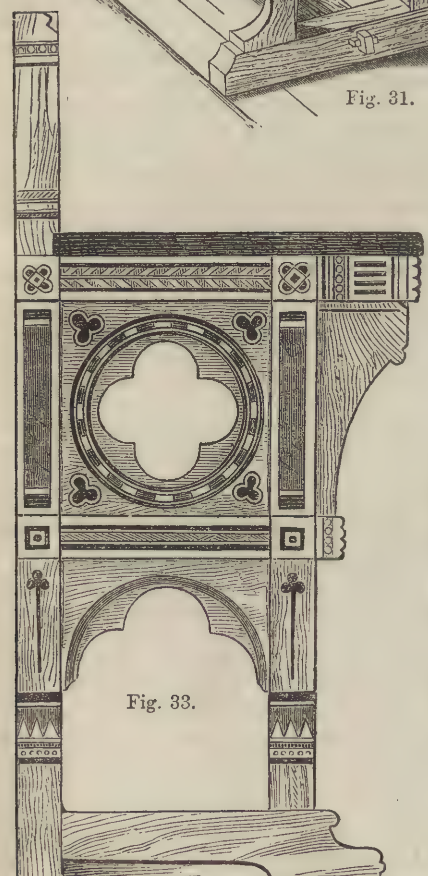


Fig. 33.

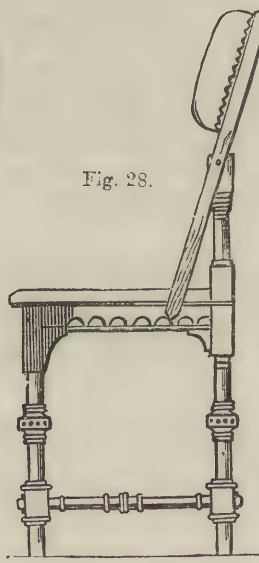


Fig. 28.

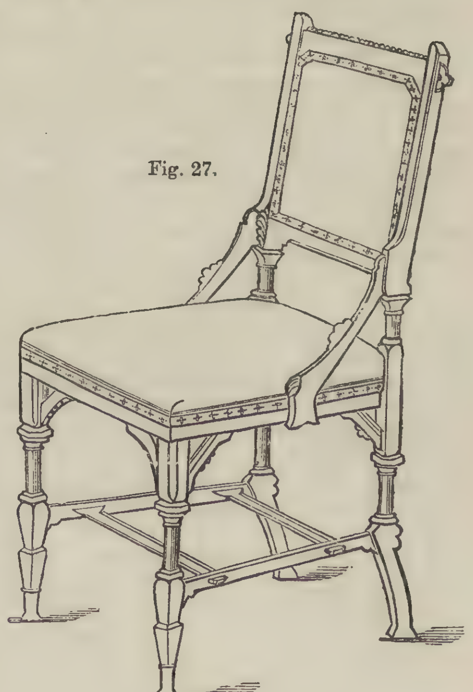


Fig. 27.

Fig. 29 is one of my sketches for Greek furniture, designed for Moor Hall. It was formed of black wood. Here the frame of the seat is first formed, and the legs are inserted beneath it, and let into it, while the wood-work of the end of the couch stands upon it, being inserted into it. This appears to have been the general method with the Greeks of forming their furniture, yet it is not so correct structurally as Fig. 30, another of my sketches, where the end and the leg are formed of one piece of wood. The first formation (that of Fig. 29) would bear any amount of pressure from above, but it is not well calculated for resisting lateral pressure; while the latter would resist this

seat, and the lower and upper thickened portions of the legs act as the brackets beneath the seat in Fig. 23. This illustration is also from Mr. Talbert's work. Fig. 32 is a table slightly altered (structurally improved, I think) from one in Mr. Eastlake's work. I see no objection to the legs leaning inwards at the top; indeed, we have here a picturesque and useful table of legitimate formation. Fig. 33 is the end elevation of a sideboard from Mr. Talbert's work. Mark the simplicity of the structure. The leading or structural lines are straight and obvious. Although Mr. Talbert is not always right, yet his book is well worthy of the most careful con-

sideration and study; and this I can truly say, that it compares favourably with all other works on furniture with which I am acquainted.

The general want which we perceive in modern furniture is simplicity of structure and truthfulness of construction. If persons would but think out the easiest mode of constructing a work before they commence to design it, and would be content with this simplicity of structure, we should have very different furniture from what we have. Think first of what is wanted, then of the material at command.

NOTABLE INVENTIONS AND INVENTORS.

IX.—POTTERY AND PORCELAIN (*continued*).

BY JOHN TIMBS.

WE now come to porcelain, first produced in China, Japan, and Mexico. Bottles of Chinese manufacture have been found in the tombs of Thebes; one of them inscribed with the date between 1575 B.C. and 1289 B.C. Porcelain was common in the Chinese Empire 163 B.C., and in its greatest perfection 1000 A.D. The porcelain tower near Nankin was erected in 1400. This "vitreous, precious stone pagoda" was first built about A.D. 200, and rebuilt A.D. 1400, when it occupied nineteen years in construction, and cost £600,000. It was of nine storeys, though commonly reported thirteen, as it was intended to be of this number. Its height was 261 feet, and diameter at the base 96 feet 10 inches. There were in it 150 bells, and 140 lamps. In 1856, Tien Wang, one of the rebel chiefs, wantonly blew up the pagoda with gunpowder, some say to spite another Wang; others, because he declared it to be too old! The fragments of this remarkable edifice were left on the spot, and were carried away by the curious.

> "So much for monuments that have forgotten
> Their very record."—*Byron.*

Marco Polo describes the manufacture in China during the thirteenth century. When specimens found their way to Europe, the Portuguese were so struck with the resemblance between the texture of this fine ware, and that of the cowry-shells, or *porcellana*, as they were called, that they imagined the ware might be made of such shells, or of a composition resembling them, and named it accordingly. They imported numerous and splendid collections into Europe, where it was called "china" from the country which produced it. The Dutch next established a traffic with India and Japan, and Europe was long supplied with porcelain through Holland. The English next shared in the trade, through the East India Company. In Queen Anne's reign china collections became a passion. Fokien now produced the pure white porcelain of China; Nankin the blue and white and pale buff porcelain; and King-te-ching the old sea-green and crackle porcelain. The ancient crackle is so much esteemed in Japan that £300 has been paid for a single specimen. The Chinese call this ware snake porcelain. The egg-shell porcelain is much prized in China; it is coloured citron-yellow for the exclusive use of the Emperor, and ruby for the use of the Imperial family. An inferior porcelain, known as Indian china, is made at Canton. Chinese porcelain is of beautiful material and delicate texture, brilliant colour, and pure glaze; but the forms and design are so hideous, that it has been said the vase of the humblest Greek potter of the best period has an æsthetic value far surpassing the most costly productions of the Celestial Empire. ("Encyclopædia Britannica," eighth edition.)

The first successful imitation of Chinese porcelain produced in Europe was by Böttcher, an apothecary's assistant, at Berlin; but he was suspected of practising the black art, and so escaped to Dresden, where, under the patronage of the Elector of Saxony, Augustus II., he made some vessels much resembling Oriental porcelain, from a brown clay found near Meissen, with a reddish tint. To preserve his secret, the Elector sent him to the fortress of Konigstein, on the Elbe, where a laboratory was prepared for him. In 1707 he returned to Meissen. Böttcher hitherto produced only a kind of red and white stoneware, but in 1709 he succeeded in producing a white porcelain, which led Augustus to establish a manufactory at Meissen, and to appoint Böttcher the director. He employed the kaoline of Ane in the Erzebirge for his porcelain, the secret of which was kept for some time. This kaoline powder was conveyed in sealed barrels, and all persons in the factory were sworn to secrecy. No visitor was admitted, the oath to the workmen was renewed every month, and when the King was allowed to enter the factory, a similar obligation was imposed on him. In each room was set up the motto, in large letters, "Be secret unto death." At length, just before the death of Böttcher in 1719, a foreman escaped from the factory to Vienna, where he submitted to be bribed, and rival factories soon sprung up in different parts of Germany. Among the finest Meissen ware are groups from antique models, figures in lace dresses, flowers studied from Nature, and vases of honeycomb china.

The first rival of Meissen was the porcelain factory of Vienna, established in 1720, but its porcelain holds a lower rank than that of Dresden or Berlin; it is remarkable for its raised and gilded work, and reliefs of solid platinum and gold. Next, at Höchst, on the Nidda, arose a celebrated pottery, the director of which carried his recipes about with him, but of which he was plundered, and the secret sold; hence originated the porcelain factories of Switzerland, of the Lower Rhine, and even of Cassel and of Berlin. The Fürstenburg works, in the Duchy of Brunswick, originated in a bribe offered by one of the dukes to a Höchst workman. The ware of the factory of Nymphenberg, in Bavaria, is much esteemed, many of the designs being from the celebrated picture-gallery of Munich. The porcelain factory of Berlin was not very successful until the fraudulent transference of the best of the workpeople and the *matériel* of the Meissen factory. The Berlin porcelain was but an imitation of the Dresden, but it yielded the King an annual revenue of 200,000 crowns. The Prince-Bishop of Fulda established a factory in a house adjoining the episcopal palace, but it failed through the dignitaries of the church claiming the privilege of carrying off specimens without paying for them. The porcelain factories of Thuringia originated about 1758, when the son of a chemist experimented on some sand which he had bought of an old woman, and obtained by its means a porcelain-like substance, which led to the erection of a factory at Sitzerode, sanctioned by the Prince of Schwartzburg. The abundance of fuel supplied by the forests of Thuringia led to the erection of several other factories, all which produced porcelain still prized by collectors. A factory established by the Empress Elizabeth, in 1756, near St. Petersburg, still produces good porcelain from native materials. Denmark has also a factory at Copenhagen, and Zurich one in Switzerland.

Meanwhile, England had been striving in the porcelain manufacture. The Bow works, closed in 1762, have been already mentioned. The mark is a crescent or *bow;* it is scarce, but never fine. This and the Chelsea were soft wares, made from a mixture of white clay, white sand from Alum Bay, and pounded glass. The Chelsea works, in an old mansion by the Thames bank (of which we have seen a view upon a fine Chelsea vase) did not flourish until George II. imported workmen, models, and materials from Brunswick and Saxony. The best period of Chelsea porcelain was between 1750 and 1755, when such was the demand for it that dealers flocked to the works, and at the doors purchased pieces as soon as they were fired. A service sent as a royal present cost £1,200. The finest works were in the style of the best German; the colours fine and vivid, and the claret colour peculiar.

At the Chelsea ovens, the celebrated Dr. Johnson, who had conceived the notion that he was possessed of a secret for making porcelain, obtained permission to have his compositions baked here, where he watched them day by day; he was not allowed to enter the mixing-room, and roughly modelled his composition in a room by himself. He failed, for none of the articles he formed would bear the heat of firing. He conceived that one simple ingredient was sufficient to form the body of porcelain; whereas, the manager of the factory declared that in the composition of the Chelsea paste no less than sixteen different substances were blended together. The Chelsea works were discontinued in 1764, when the manufacture was removed to Derby, and the ware was called Chelsea-Derby. It has the mark of a D, crossed by an anchor; it is very beautiful, but dear as silver. At the Bernal sale, in 1855, a pair of scalloped Chelsea vases, painted with birds, brought £110 5s.; at Sir John Macdonald's sale, in 1850, a pair of Chelsea cups and saucers brought £36 15s; and in 1870, from the Bulteel

collection, were sold an old Chelsea vase and cover, and a pair of vases and cover, painted with medallions, on pedestals, for 355 guineas. Nearly opposite Chelsea were the Battersea enamel works, at York House, where Ravenet and others drew for Alderman Jansen, but the factory was soon closed.

The Derby factory was established in 1750, and became most famous by the junction of the Chelsea artists already named. Flaxman designed for the establishment. Mr. Marryat describes the Derby porcelain as being very transparent, of fine quality, and distinguished by a beautiful bright blue, the ground being generally plain; the white biscuit figures are said to equal those of Sèvres.

The Worcester works were established in 1751, by Dr. Wall and some others. They first imitated blue and white Nankin china; they afterwards adopted the Sèvres style, with the Dresden method of painting. At these works were first used the Cornish stone, or kaoline, discovered in 1768. The early productions of their proprietors, Messrs. Chamberlain, bring great prices. The works are now carried on with renewed success by Messrs. Kerr and Binns, who claim for Worcester the invention of transfer printing on porcelain, from copper-plates; the first specimen, a small mug, brings a very high price. The "blue Worcester" ware is also deservedly in high repute.

Shropshire has long been famous for its porcelain factories. In 1772, at Caughley, near Broseley, was established the factory, chiefly for blue and white, and blue, white, and gold porcelain, known as Salopian ware. At Coalport, earthenware is made similar to the Etrurian or Wedgwood ware, of which we have already spoken, and here are the works of Rose and Co., famous for their porcelain of rose ground, the nearest approach to *rose de Barri*.

The Staffordshire works are concluded to be of Roman origin, evident remains of Roman potteries having been repeatedly discovered at a considerable depth below the present surface. The county is unrivalled in amount of production of pottery. The Minton factory is famous for its imitation of old Sèvres and its flower-painting, its enormous majolica vases, its Persian figures, and its hard porcelain for chemical purposes; its crucibles and capsules have stood the severest tests, equal to German ware. Messrs. Copeland, at Stoke, are noted for their exquisite busts, manufactured from porcelain earth, and copied from the antique. Their flower-painting and gilding are very fine, and they have supplied 36,000 tiles or slabs for the ceilings of nine lofty and spacious domes in the Imperial library at Paris.

Early in the present century good porcelain was made at Nantgarrow and Swansea; it is also stated that the Bristol china, a white ware, formerly common in the west of England, was made in Wales, and sold in Bristol. At the Rockingham works, in 1837, was completed for William IV. a superb dessert service of 200 pieces of porcelain, painted with 700 subjects; it had occupied five years, and cost upwards of 3,000 guineas. From the same works we have seen a fac-simile of a small Roman jug, dug up at Caistor, in Lincolnshire, of which the ground colour was red, with raised ornamentation of fern leaves of darker red.

France, though possessing taste, skill, and science, was unable to compete with other nations for want of a suitable raw material. A cunning Jesuit in China forwarded to France specimens of the earths used in the composition of Chinese porcelain, by which Reaumur, the celebrated chemist, discovered the true nature of porcelain to be a semi-vitrified compound, in which one portion becomes infusible at the greatest heat to which it can be exposed; while the other portion vitrifies at that heat, and enveloping the infusible part, produces that smooth, compact, and shining texture, as well as transparency, which are distinctive of true porcelain. All that was then wanting for the perfect imitation was the discovery of materials similar to those received from China, the search for which was speedily successful. The first establishment was formed in the Castle of Vincennes, whence, in 1756, it was transferred to Sèvres. In 1760, Louis XV., at the solicitation of Madame de Pompadour, bought up the establishment. The factory became celebrated for its soft porcelain, or *pâte tendre;* but the great object was to produce the hard porcelain, which had rendered Saxony the envy of Europe. Then kaoline was not known in France, nor was its presence suspected until, about 1768, the wife of a surgeon, near Limoges, noticed there a white unctuous earth, which she tried to use as an economical substitute in her house for soap. Her husband showed a portion of the earth to an apothecary at Bordeaux, who, being aware of the search making for kaoline, sent a specimen of the Limoges earth to the chemist Macquer, who at once recognised it as the desired kaoline. He then established the manufacture of hard porcelain at Sèvres, in 1769; but such was the difficulty in suiting the colours to the less absorbent material that soft porcelain continued to be made until the year 1804. The *pâte tendre* was not considered as real porcelain; it was of complicated and expensive composition, and liable to collapse during the firing. Mr. Marryat speaks of it as "remarkable for its creamy and pearly softness of colour, the beauty of its paintings, and its depth of glaze." The ware for common use was painted with flowers, in patterns, or medallions; that for royal use had grounds of *bleu de roi*, blue turquoise, jonquill or yellow, green, and a lively pink, the *rose du Barri*. Some specimens were painted with landscapes, flowers, birds, boys, and Cupids, in medallions, and others with subjects after Watteau; and the jewelled cups, with the *bleu de roi* ground, were celebrated. In form the Sèvres china is not equal to the Dresden. Such was its profuseness of decoration that a law was passed in 1766, and renewed in 1784, limiting the use of gold in the decoration of porcelain at the royal manufactory at Sèvres, which accounts for the rarity of the old French gilded porcelain. This being a royal establishment, all Sèvres porcelain had on its under-surface an initial mark in blue, surmounted with the French crown.

TECHNICAL DRAWING.—XXIV.

DRAWING FOR MACHINISTS AND ENGINEERS.

TOOTHED WHEELS (*continued*)

FIG. 235.—*System composed of a rack driving a pinion.*

Here the curves of the faces of the teeth in the rack are portions of a cycloid generated by the circle A, the diameter of which is half that of the pitch-circle B, rolling on the pitch-line C D.

In commencing this study, draw the pitch-line, and a perpendicular, on which set off the centre of the pitch-circle and the generating circle.

Draw both of these circles, the tangent point being at T.

Set off the length of the pitch along the rack and on the pitch-circle, and proceed to divide each pitch into a tooth and a space.

Now describe the cycloid which is to give the face of the teeth of the rack. If the drawing be large, or one from which a "pattern" is to be made, this cycloid may be cut in thin wood so as to form a templet (described in a previous lesson), and with this the faces of the teeth of the rack may be described; but for general use in smaller drawings the curve may be an arc of a circle, the radius of which is the length of the pitch, as shown at G H.

The flanks of the teeth of the rack are perpendiculars, and are strengthened by being joined by quadrants to the line parallel to the pitch-line, which forms the root of the teeth.

The curve of the faces of the teeth of the pinion are portions of the *involute* of the pitch-circle.

For a full description of the nature of this curve, and the method of describing it, the student is referred to Lesson VI. in "Practical Geometry applied to Linear Drawing."

Fig. 236 will remind the student of the general principles of its construction.

Let A B be a portion of the circle from which the curve is to be evolved, divided into a number of equal parts; as, 1, 2, 3, 4, 5, 6.

At these points draw radii, and draw tangents to each.

From the points of tangent set off on these lines divisions corresponding to the figure from which each is drawn. Thus, on tangent 1 set off *one* of the divisions, from tangent No. 2 set off *two*, and so on, and through the points so obtained the involute is to be drawn. Here, again, for general purposes in drawing, the arc of a circle is substituted for the true curve, and it will be seen that the arc struck with a radius equal to a pitch corresponds nearly (though not perfectly) with the curve shown at B (Fig. 236).

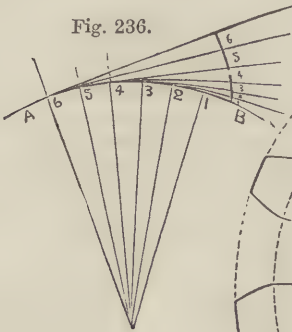
The flanks of the teeth are radial, turned off into the inner circle by small arcs.

The remaining portion of the pinion will be easily completed without further explanation. The space at H, as the student will no doubt know, is the *key-bed*, in which a key is placed to fasten the pinion on the journal or end of the shaft.

being taken as equal, the radius of the pins is therefore one quarter of the pitch.

The spaces in the pinion are struck with the same radius. The curve of the faces of the teeth is, as has already been said, a portion of the epicycloid; but an arc drawn from A, the middle of a pitch, so nearly coincides with the curve B C, which

Fig. 236.



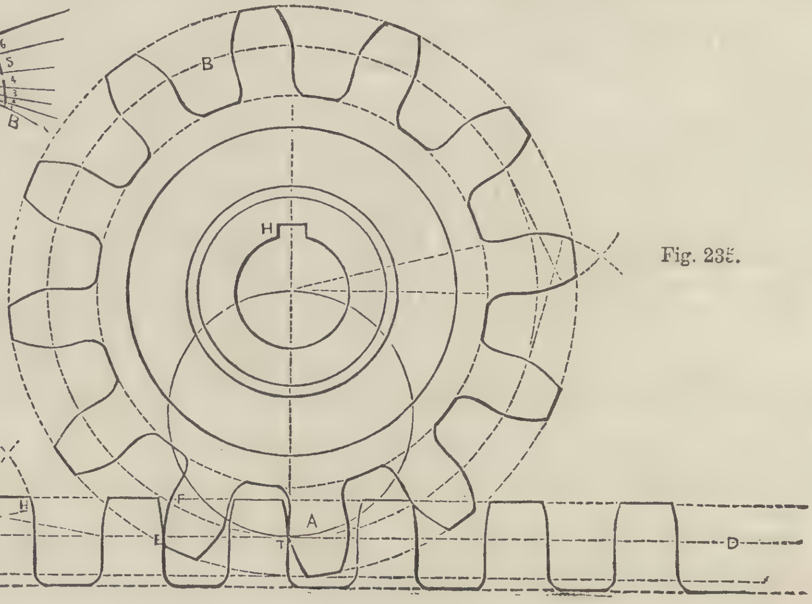


Fig. 235.

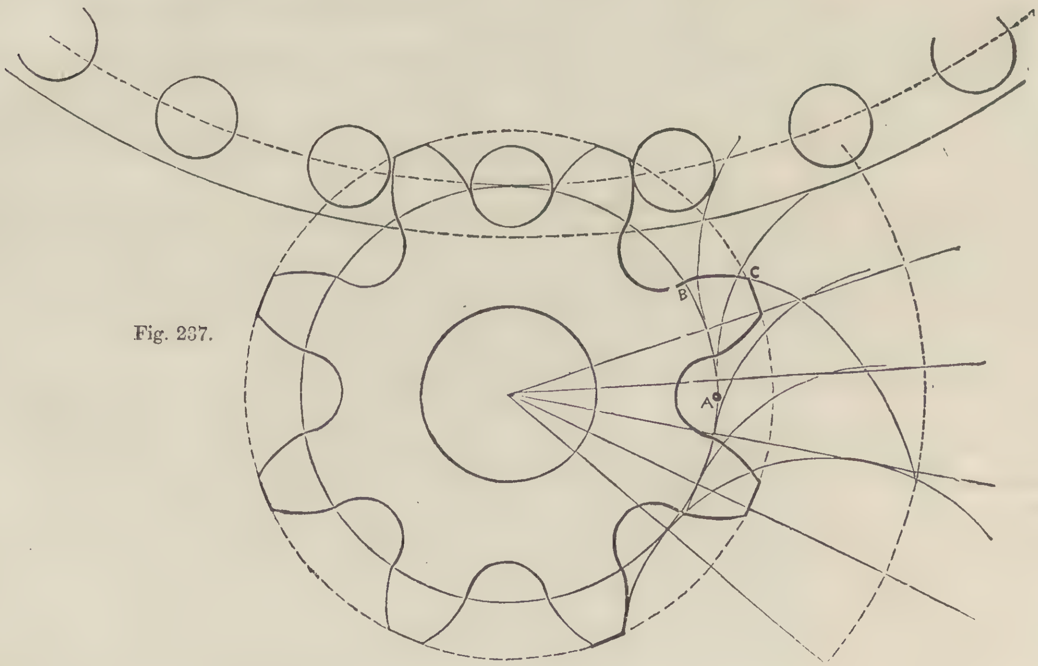


Fig. 237.

Fig. 237.—In the system here shown, the pinion drives a wheel with pins instead of teeth, and the face of the tooth of the driver is a portion of the epicycloid curve generated by a circle of half the circumference of the wheel.

In copying this example, the pitch-circles of driver and follower having been described, and the pitches having been set off on each, the circles representing the pins are to be drawn. The spaces and diameter of the pins in this instance

is the curve properly constructed, that in drawings it is usually substituted for it.

The following important remarks on the teeth of wheels are made by Professor Goodeve :—

"It will be proved, when we treat of rolling curves, that the surface of one tooth must always slide upon that of another in contact with it, except at the moment when the point of contact is passing the line of centres.

"This matter should be well understood. The teeth are perpetually rubbing and grinding against each other; we cannot prevent their doing so; our rules only enable us so to shape the acting surfaces, that the pitch-circles shall roll upon each other.

"Nothing has been said about the teeth rolling upon each other. It is the pitch-circles that roll; the teeth themselves slide and rub during every part of the action which takes place out of the line of centres.

"Since, then, the friction of the teeth is unavoidable, it only remains to reduce it as much as possible, which will be effected by keeping the arc of action of two teeth within reasonable limits.

"Generally, the friction before a tooth passes the line of centres is more injurious than that which occurs after the tooth has passed the same line. The difference between drawing a walking-stick along the ground after you, and pushing it before you, is given by Mr. Denison as an illustration of the difference between the friction before and after the line of centres; but this difference is less appreciable when the arc of contact is not excessive."

MECHANICAL DRAWING FROM ROUGH SKETCHES.

In the previous figures the student has been allowed to copy the examples by measurement, or to increase their sizes as he may think proper.

By such means, however, only practice in *copying* ready-made drawings is obtained, and such practice must only be taken as the means to the end—certainly not as the result to be attained; for a draughtsman who can but copy is, indeed, little better than a machine; being merely capable of measuring accurately and drawing fine lines, most of the latter result being due to his instruments, he thus becomes, in the true sense of the term, a "mechanical draughtsman."

It is to avoid this that the course here laid down blends mental study with manual practice, and in the present section an endeavour is made to afford the student practice in working from rough sketches, such as are made in an off-hand manner by the engineer, and entrusted to the occupants of the drawing-office to work out.

These sketches, though approximately correct in *general* proportions, are not drawn to any absolute scale; *the student must not, therefore, trust to measuring from them.* The true measurements are, however, marked on each part, and the student is to take these from his scale. He is advised to work Fig. 238 (which is a rough hand-sketch of a small copying-press) to a scale of not less than $\frac{3}{8}$ of an inch to an inch.

To make this scale, draw a straight line, and on it set off a number of divisions of $\frac{3}{8}$ of an inch each. Mark the beginning of the line O, the first division 1, the second 2, and so on; these divisions will then represent inches. This plan is better than measuring direct from the foot-rule, as it avoids the necessity of calculating how many inches so many times $\frac{3}{8}$ make, by which errors often occur.

Now divide one of the above spaces into eighths for measuring the fractional parts of inches.

The scale being thus prepared, draw the base-line, A B, and the central perpendicular, C D.

Next mark off 9″ on each side of C—viz., C E and C F—the length of the base being 18″.

Draw perpendiculars indefinitely high at E and F; mark off on one of these $1\frac{3}{4}$ inch—viz., E G. It is not necessary to measure this height on *both* perpendiculars, for by placing the T-square against G, the line G H will give the height of F H.

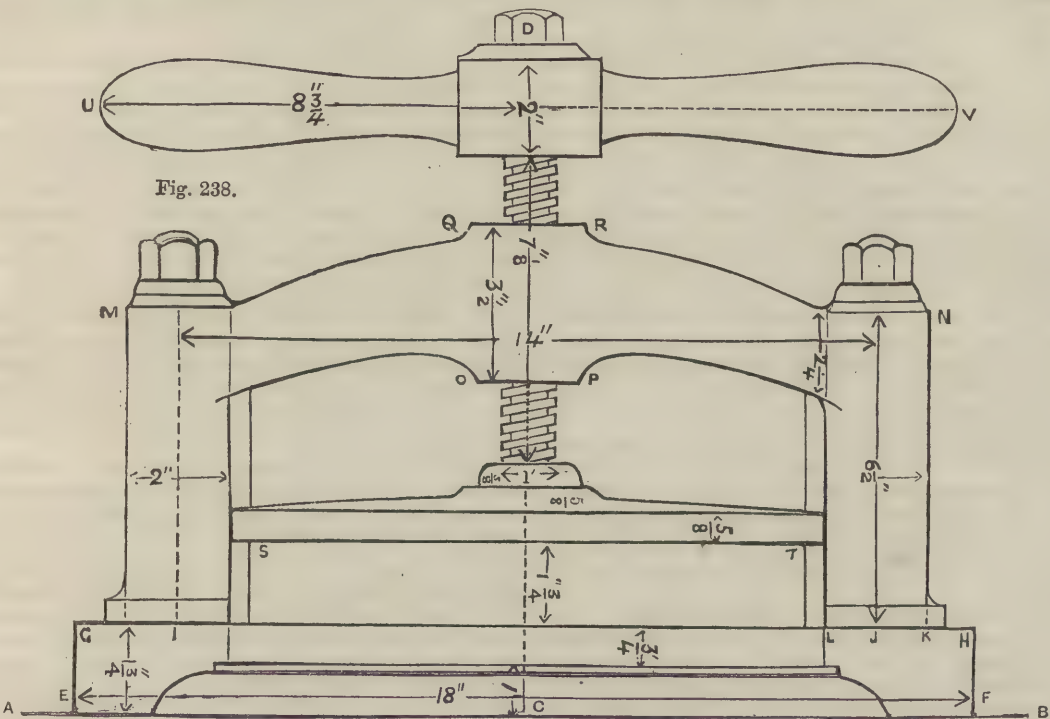


Fig. 238.

On each side of the centre line now set off 7″, and erect the perpendiculars I and J for the centre lines for the standards; the width from centre to centre being 14″.

On each side of I and J set off J K, draw the lines K, L (and corresponding lines on the opposite side), and draw the horizontal M N at $6\frac{1}{2}$″ above G H.

Now draw the horizontal O P at $5\frac{1}{2}$″ above G H, and Q R at $3\frac{1}{2}$″ above it; the width of O P is $2\frac{1}{4}$″, and of Q R $2\frac{1}{2}$″. The arches are then to be drawn from centres on the perpendicular, C.

The iron lid, S T, is, in the present view, at $1\frac{3}{4}$″ above G H; it is $\frac{5}{8}$″ thick. On it is a boss $\frac{5}{8}$″ thick, to which a flange runs from each corner, and on this boss is a box $\frac{5}{8}$′ high, in which the end of the screw works.

From this box, the screw, which is 1″ in diameter, is $7\frac{1}{8}$″ long.

At 1″ above this draw U V, the central horizontal, for the handle.

The boss in the middle of the handle is 2″ high and 3″ diameter. The length from end to end of the handle is $17\frac{1}{2}$″.

The screw is to be drawn in straight lines, as shown in previous examples. The nuts, etc., will be easily understood without further instructions.

ANIMAL COMMERCIAL PRODUCTS.—XVI.

PRODUCTS OF SUB-KINGDOM ANNULOSA (*continued*).

Blister Fly (*Cantharis vesicatoria*).—A small coleopterous insect about three-fourths of an inch long, of a nauseous odour and a brilliant golden-green colour. These insects secrete in their bodies a principle which has the power of vesicating or blistering the human skin when applied. For this purpose the beetle is reduced to powder, which, mixed with ointment or lard, is spread thinly upon a piece of leather, and then applied to the part intended to be blistered. The blister fly is found on a variety of shrubs in Spain, Italy, France, etc. It has been taken occasionally in England, but it is much more abundant in Spain; and although we now receive it principally from Astracan and Sicily, it still retains its usual commercial name of Spanish fly. In some years as many as twelve tons of these insects have been shipped from Sicily. Some idea of the immense number destroyed to form that amount may be obtained from the fact that fifty of them scarcely weigh a drachm.

Lac Insect (*Coccus lacca*).—The habits and economy of this insect are much the same as those of the cochineal. The lac insect attaches itself to the bark of trees abounding in milky juice—such as the *Ficus Indica* or Indian fig, and the *Ficus religiosa* or Banyan fig—punctures the bark, and causes an exudation of the milky juice; this eventually surrounds the lac insect, her eggs, and larva, producing an irregular resinous-looking brown mass on the branch, which it encircles. The commercial varieties of lac are *stick lac*, which is the substance in its natural state investing the small twigs of the tree; *seed lac*, the same substance broken off in small pieces from the twigs; and *shell lac*, consisting of the substance melted and formed into thin cakes. Seed lac and shell lac are the resin left after the dye has been extracted from the stick lac. Lac dye and lac lake are two preparations of the colouring matter of stick lac, imported in small cubic cakes from the East Indies. The colouring matter of these dyes much resembles cochineal, for which it is largely substituted. Upwards of 1,000,000 lb. are annually imported from Bengal, and 3,000,000 lb. of shell lac; nearly one-half of it, however, is again exported to Italy, Germany, and other parts of the Continent.

Lac is mainly consumed in the manufacture of dye stuffs, sealing-wax, and of certain varnishes and lacquers. Red sealing-wax has its colour communicated by vermilion; white sealing-wax is made with bleached gum lac; black sealing-wax is a mixture of shell lac and ivory black; and blue sealing-wax is made by colouring the shell lac with smalt or verditer. To make golden sealing-wax, powdered yellow mica is mixed with the shell lac.

PRODUCTS OF THE SUB-KINGDOM RADIATA.

Radiata (Latin, *radius*, a ray) is the fourth primary division of the animal kingdom, and includes all those animals which have a radiated disposition of the organs of locomotion and internal viscera around a common centre, whence the term *radiated animals*. Their nervous system and instincts are reduced almost to a nullity; all are indolent and slow of movement, while many of them are rooted and fixed. They have been subdivided into the following classes:—

1. *Echinodermata* (Greek, *echinos*, a hedgehog, and *derma*, the skin), or spiny-skinned animals. Examples: asterias or sea-star, and the common echinus or sea-egg.

2. *Acalephæ*, or jelly-fishes, called also sea-nettles, because leaving, when touched, a disagreeable sensation, like the sting of a nettle. These have an extremely soft, gelatinous structure, and float and swim in the water by alternate contractions and dilatations of the body.

3. *Polypi*, or animals having a fleshy cylindrical hollow body, the mouth of which is surrounded by numerous arms or tentaculæ, and commonly fixed by one end. Examples: hydra or water polyp and the coral polyps.

Of the above classes of radiated animals, the last only is of commercial importance; it furnishes us with the

Red Coral (*Corallium rubrum*, L.).—This is a marine production, formed by numerous polyps in union with each other, called a polypidom. Recently taken, coral is covered with one continuous living membrane, in which are the polyp cells. These polyps produce the coral, a branched tree-like structure, beautifully red, and very hard, and for this reason much sought after for ornamental purposes. In places where good coral is obtained it forms an important article of commerce. It is abundant in various parts of the Mediterranean Sea. It occurs in the Red Sea, the Persian Gulf, and on the coasts of Spain, France, Corsica, Sardinia, and Sicily. Very fine coral is found between Tunis and Algiers, off the coast of Barbary, where the French and Italians carry on the coral fisheries. Other species of the genus have from time to time been dredged off Madeira and the Sandwich Isles.

Coral always grows perpendicularly on the surface of the rock to which it attaches itself, in whatever position the rock may be placed, and from eight to twelve inches in height. Coral requires from eight to ten years to arrive at its full growth. It is dredged up from depths varying from 10 to 1,100 fathoms. Its value depends on its size, solidity, and the depth and brilliancy of its colour. Some of the corals in the market are worth from eight to ten guineas an ounce, whilst other kinds will not fetch one shilling a pound.

PRODUCTS OF THE SUB-KINGDOM PROTOZOA.

Protozoa, or first animals (Greek, *protos*, first, and *zoon*, an animal). Examples: Infusoria, or animalculæ developed in vegetable infusions and sponges.

Sponge (*Spongia officinalis*, L.).—This organism is now acknowledged by naturalists as belonging to the animal world. A piece of sponge shows on its surface an indefinite number of minute holes, amongst which there are larger openings scattered. When alive and in the water, currents of water are seen to enter the smaller openings, which, after passing through the body of the sponge, are ejected out of the larger orifices. Nutritive matter is conveyed by these currents into the body of the sponge, and fæcal matter is at the same time removed. A coating of living gelatinous matter is spread all over the fibres of the sponge, in consistence like the white of an egg. This runs away freely from the sponge when the latter is taken out of the water. Nothing then remains visible but the sponge, which is, in fact, the horny skeleton or structure formed by the labours of the animals constituting the gelatinous coating.

Sponges occur in all seas, from the equator to the poles, but they attain their greatest size and perfection in the tropics. They grow on anything which will serve them as a point of attachment.

Several kinds of sponge come into the market, but the most valuable, and those also most in general use, are called Turkey and West India sponges. The former is considered to be the best. The tubes and orifices of the Turkey sponge are smaller than those of the West India variety; it is also more durable, and less easily torn. The Turkey sponge is obtained from the Mediterranean, where it grows on rocks and stones at the bottom of the sea in masses from the size of an egg to that of a man's head. Our supplies are received from Cyprus and Candia, from the shores of Anatolia, and from several islands of the Grecian Archipelago, especially from the small island of Symis or Syme, whose inhabitants are said to be the best divers. The coast of Syria furnishes the finest toilette sponges, valued at from 35s. to 40s. per pound; ordinary sponge costing only 10s. per pound. Inferior sponge, with a large-holed texture, called horse sponge, comes from the coasts of Barbary, Tunis, and Algiers. The annual importation into the United Kingdom amounts to between 200,000 and 300,000 pounds, valued at £80,000. The coarser sponges come principally from America. Very large ones are obtained from the Bahama banks and the coast of Florida.

The property which sponge possesses, of absorbing water into its tubes and retaining it until squeezed out, renders it valuable for all purposes involving washing and cleansing.

PRACTICAL PERSPECTIVE.—IV.

FIG. 20.—The subject of this lesson is a cross, made of square timber, or stone.

The picture-line, height of spectator centre, and points of distance having been fixed at pleasure,

From A set off A B, representing the distance of the perpendicular of the cross on the left of the spectator, and beyond this mark off C′, so that B C′ may equal the thickness of the material of which the cross is supposed to be made. Draw the perpendiculars C′ E and B D, and join them by the horizontal E D.

At the required height from the picture-line draw the horizontal line G I.

Make I I′ and G′ G equal to C′ B. At G and I erect perpendiculars, also equal to C′ B. Draw F F′ and H H′, and these will complete the front elevation of the cross.

Now from the angles B, D, G, H, I, and I′ draw lines to the centre of the picture. From B set off B J equal to C′ B.

From J draw a line to the point of distance, cutting B C in K.

At K erect a perpendicular, cutting I′ C in L, and meeting D C in M.

Through L draw a horizontal line, cutting I C in N, and G C in O.

At N erect a perpendicular, meeting H C in P, which will complete the perspective view of the cross when standing in the immediate foreground, on the left of the spectator, its elevation being parallel to the plane of the picture.

Fig. 21.—In this study the cross is represented as rotated, so that the elevation is at right angles to the plane of the picture. The attention of the student is called to the fact that whilst in the former view the foot of the cross was on the picture-line, it is not so in the present study. A moment's reflection will show that the upright must recede from the foreground in order

From J mark off J K, equal to J B, and from K draw a line to the centre of the picture.

Draw B′ K′ parallel to J K, which will be the bottom line of the upright of the cross.

At K′ draw a perpendicular, meeting a horizontal drawn from D in M.

On K erect a perpendicular, K S′, and a line drawn from S′ to the centre of the picture should pass through M.

Draw horizontal lines from H and I, cutting K S′ in P and N. Strengthen P N, and the square H I N P will be the end of the cross-arm.

From N draw a line to the centre of the picture, cutting K′ M in L. Draw I′ L, which will give the junction of the arm with the upright; a horizontal line from G will then complete the view.

Strengthen the lines required in the projection itself, in order that the object may stand clearly out.

Fig. 22.—The object of this study is to show the method of putting steps into perspective.

The four steps are contained within the square A B C D. Having drawn this square, and divided it into the required number of squares (that is, provided the steps are *squares*,

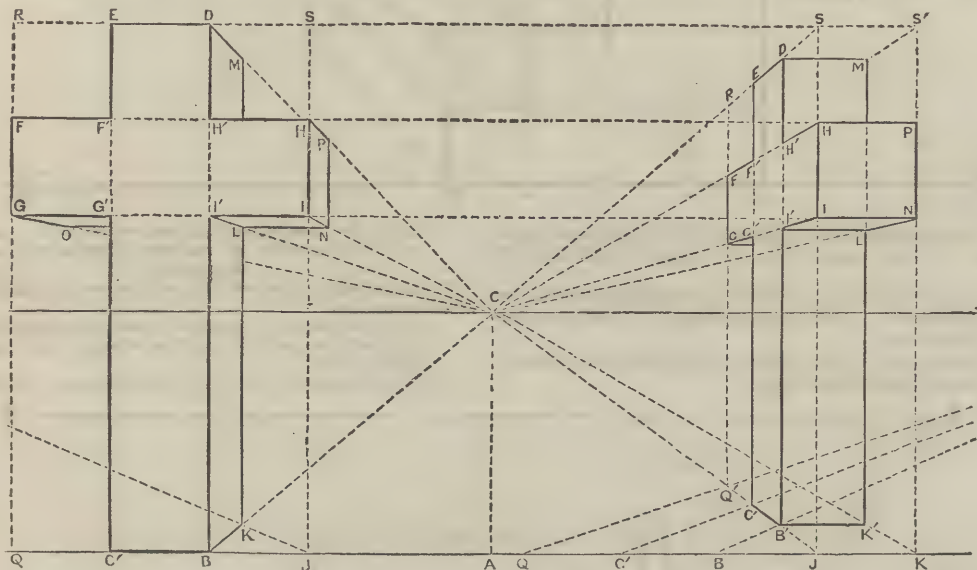


Fig. 20.

Fig. 21.

to allow of the projection of the arm, the end of which touches the picture-plane.

Now let us suppose the first cross to be moved along the picture-plane until the point J is at J of Fig. 21. If, then, on this point J we erect the perpendicular J S, and rotate the rectangle J S R Q′ on this, as a door on its hinges, we shall obtain the figure in which the cross will be contained.

Having erected the perpendicular J S, draw a line from each of these points to the centre of the picture. Mark off from J the length J Q (Fig. 20), and from Q draw a line to the point of distance, cutting J C in Q′.

Draw Q′ R, which will complete the perspective representation of the rectangle containing the cross, when its plane is at right angles to the plane of the picture.

On J S set off I and H, equal to the height and thickness of the arms.

On the picture-line set off from J the length of the arms J B and C′ Q, thus leaving between them the width of the upright of the cross. In the present study these are all equal, but of course this is not necessarily the case.

From B and C′ draw lines to the point of distance, cutting J Q′ in B′, C′; at these points erect the perpendiculars B′ D and C′ E.

From H and I draw lines to the centre of the picture, and draw F G, which will complete the perspective view of the elevation of the cross.

It now remains to give the appearance of solidity to this representation.

otherwise the containing figure must be an oblong formed of the required number of steps of the desired proportions), strengthen such of the lines as are required to form the angles of the steps—viz, B I, I F, F E, E G, G H, H I′, I′ J, J D.

From each of these points draw a line to the centre of the picture.

From B set off on the picture-line B K, equal to the real length of the front of the steps.

From K draw a line to the point of distance, cutting B C in K′.

At K′ draw the perpendicular K′ I″, and from I″ draw the horizontal I″ F′; continue the perpendiculars and horizontals, F′, E′, G′, H′, I′, J′, and D′, which will complete the figure.

Fig. 23.—The subject of this lesson is the same block of steps, turned so that their length is parallel to the picture-plane.

From A, the point immediately under the centre of the picture, set off A B, the distance of the object on the right of the spectator.

At B erect a perpendicular, B C′, equal to the height of the containing square or parallelogram.

From B and C′ draw lines to the centre of the picture.

From B set off B A′, equal to the base of the containing square or rectangle.

From A′ draw a line to the point of distance, cutting B C in A″.

At A″ draw the perpendicular A″ D; then B C′ D A″ is the perspective representation of the containing figure.

On B C′ set off the divisions corresponding with the number and height of the steps—viz., 1, 2, 3, and from these points

draw lines to the centre of the picture. On B A′ set off the divisions corresponding with the number and width of the treads of the steps—viz., 1, 2, 3.

From 1, 2, 3 draw lines to the point of distance, cutting B A″ in 1′ 2′ 3′.

At 1′ 2′ 3′ erect perpendiculars, and these cutting the lines drawn from 1 2 3 (in the line B C′) to the centre of the picture will give the angles of the steps E, F, G, H, I, J, and will thus

EXERCISE 11.

There is a stone cross, the perpendicular of which up to the arm is 7 feet; this perpendicular is at base 1 foot square. The arm, which is 1 foot square, rests on the perpendicular, and stands out 2 feet on each side; above this arm the perpendicular is continued so as to make the total height of the cross 10 feet. The scale is ½ inch to the foot, the height of the spectator is 5 feet, the distance 12 feet.

(1.) Put this cross into perspective when standing in the foreground at 8 feet on the left of the spectator.

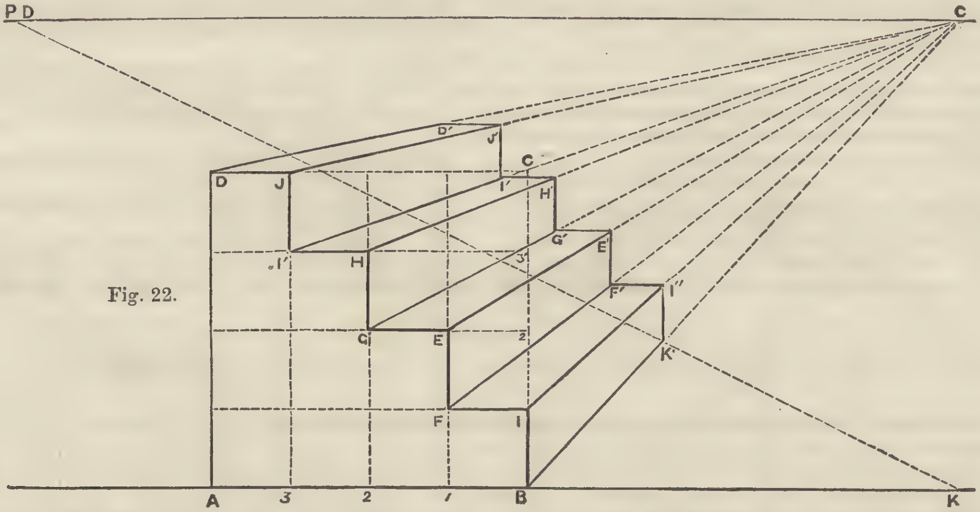


Fig. 22.

complete the perspective view of the end of the block of steps. From B set off B K, equal to the real length of the front of the steps.

Now from I (on the line B C′) draw a horizontal, and from K draw a perpendicular. These, intersecting in I′, will give the front of the first step.

From I′ draw a line to the centre of the picture, and from E draw a horizontal to intersect it in E′.

(2.) Put the same subject into perspective, at the same distance on left of spectator, but standing 10 feet back in the picture.

EXERCISE 12.

The scale, height of spectator, and distance the same as in the previous exercise.

(1.) Put the cross into perspective when standing at 9 feet on the right of the spectator, its face being at right angles to the picture-plane.

(2.) Put the same cross into perspective when standing at 6 feet

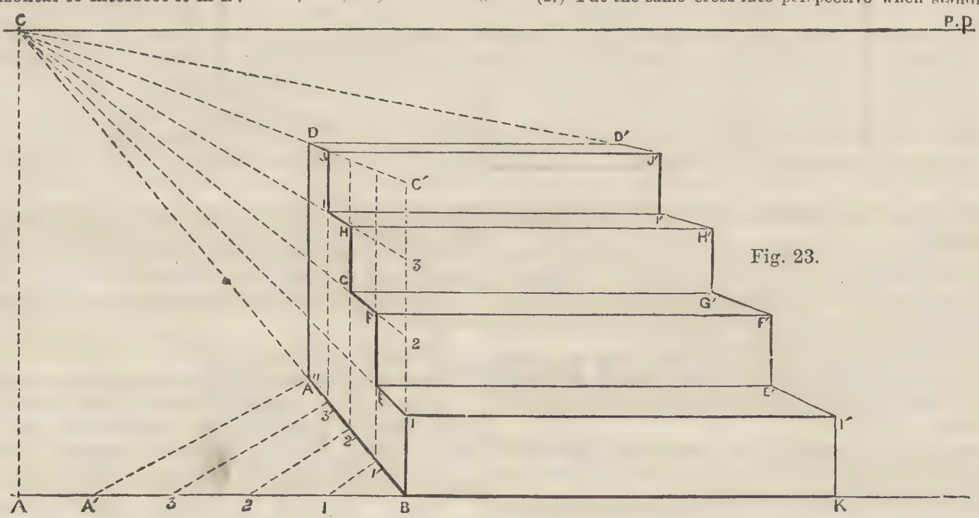


Fig. 23.

At E′ erect a perpendicular, and from F draw a horizontal to intersect it in F′.

From F′ draw a line to the centre of the picture, and intersect it by a horizontal drawn from G, thus obtaining the point G′.

From G′ draw a perpendicular, and from H draw a horizontal to intersect it in H′.

From H′ draw a line to the centre of the picture, and a horizontal from I to intersect it in I′.

At I′ erect a perpendicular, and intersect it in J′ by a horizontal drawn from J.

From J′ draw a line to the centre of the picture, and intersect it in D′ by a line from D, which will complete the study.

on the right of the spectator, and 8 feet within the picture, its face being at right angles to the picture-plane.

EXERCISE 13.

The scale is ½ inch to the foot, the height of the spectator is 6 feet, and his distance 15 feet.

There is a flight of 6 stone steps; the rise is 6 inches and the tread 9 inches, and the length of the steps 6 feet by scale.

(1.) Put this block of steps into perspective when placed at 7 feet on the left of the spectator, the end elevation being parallel to the picture-plane.

(2.) Put into perspective the same block of steps when standing so that their long edges are parallel with the picture-plane, the end elevation being at 5 feet on the right of the spectator.

CIVIL ENGINEERING.—V.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

CANALS (*continued*).

THE engineer having decided upon the most desirable course to be taken by the canal—the centre line having been staked out—next proceeds to lay out the *centres of cutting* for the various sections. These points will best be understood and explained by the help of diagrams. In excavating for the bed of a canal it is very seldom necessary to dig out soil equal to the capacity of the intended channel, because, in almost every case, the soil which is excavated can be utilised on the spot, by being deposited upon one or both sides of the excavation, and, by properly puddling and solidifying it, making it form the upper portions of the bed or the banks. Thus, frequently, nearly half the labour and expense is saved.

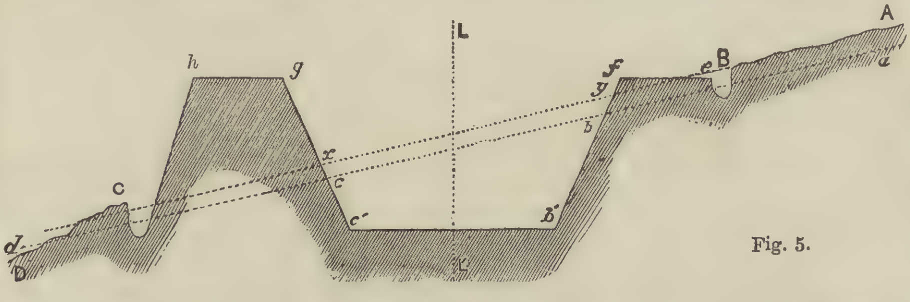


Fig. 5.

To accomplish this, however, it will be necessary to determine what shall be the depth and capacity of the excavation, so that, when the soil taken out is banked upon its margins, the completed channel shall have the capacity and dimensions it is intended the canal shall have. Now, it is with the view of determining this point that the "centre of cutting" is required.

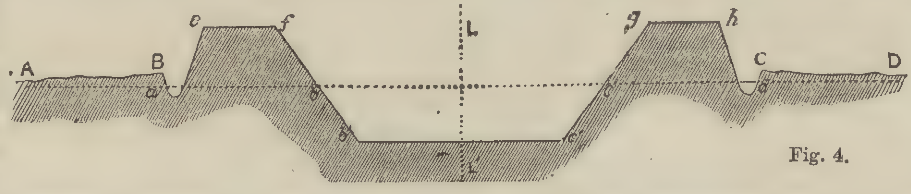


Fig. 4.

Our space prevents our entering fully into the rules requisite for determining the position of this point, which will vary greatly according to circumstances, and principally according to the direction, slope, or angle of the original surface of the ground, relative to a line standing vertically in the centre of the channel.

Let A B C D (Fig. 4) represent the surface of the ground, and let the first condition of the surface be that of a horizontal plain. This line will then be at right angles to L L′, the line standing vertically in the centre of the channel. In this case the dotted line $a\ b\ c\ d$, in which lies the centre of cutting, will occupy such a position as that the area of the quadrangle $b\,c\,c'\,b'$ shall be equal to the sum of the areas of the quadrangles $a\,e\,f\,b + c\,g\,h\,d$, in which $e\,f$ and $g\,h$ are the towing-paths on the sides of the channel $f\,g\,c'\,b'$, the small grip or ditch at a and d being formed to carry off the drainage from the banks.

The enormous advantages which result from the adoption of this plan become apparent from an examination of the diagram. It will there be seen that only the lower and narrower portion of the channel has really to be excavated, the upper and wider part being built up, as it were, of the excavated soil.

The second condition we have to consider is, when the surface-line of the ground A B C D (Fig. 5) is not at right angles with the vertical line L L′. In this case it may not be necessary to disturb the ground at all upon the upper side of the slope, except to excavate for the towing-path $e\,f$, and the drain at B. The line $a\,b\,c\,d$ through the centre of cutting will, in this instance, be determined upon by the consideration that the whole of the excavated soil can be utilised upon the lower side of the channel only; the capacity, therefore, of the figure $y\,b'\,c'\,x$ must equal that of the figure $x\,g\,h$ C, $y\,x$ being in the line of the ground level, $e\,f$ and $g\,h$ being the towing-paths, and $f\,b'\,c'\,y$ the channel of the canal.

It will be necessary to give one rule only for obtaining the centre of cutting. Take a case of *oblique cutting*—*i.e.*, where the canal has to be formed on the side of a hill, the inside and outside slopes being parallel, and one bank only required:—Let A B C D (Fig. 6) be the section of the intended canal, and C D E G F that of the bank, the slopes A B and E F being parallel. To find the centre of cutting, continue the lines B C, D E to G and A; draw the perpendiculars C m, D n, and the diagonals A G, $m\,n$, intersecting at p; through p draw the parallel $s\,p\,t$, and bisect it in o; then o will be the centre of cutting, and if any line, H O F, be drawn through this point, cutting the slopes A B, E G produced, H B C w will always be equal to w D E F; and the total breadth of the canal and bank (A D + n G) will be to the breadth of the bank added to the base of the slope (n G + n C), as the depth of the canal from its surface is to the depth below the centre of cutting. This point o will also be the centre of cut and cover, for a line staked out at the level of the ground above the point o will show the middle of the land required for the canal.

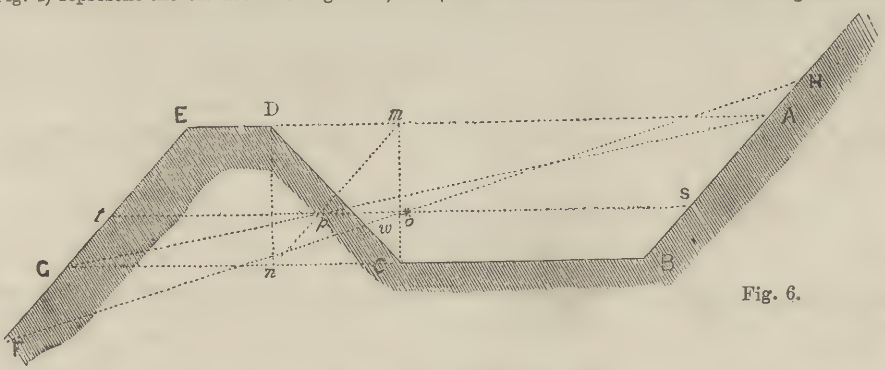


Fig. 6.

Cases may arise, however, in which the excavated earth cannot be utilised. The soil may be entirely unsuited for the formation of the banks, and must be removed. In such a case the channel will have to be altogether excavated below the ground-level. Sometimes, as, for instance, in passing through towns, retaining walls have to be built, so that less breadth of land shall be required. In conveying canals over roads, or across ravines, it may be necessary to construct aqueducts of masonry, or troughs of iron. A handsome bridge of five arches, built of hard sandstone, conveys the Lancaster and Kendal Canal over the river Lune at a height of 62 feet above the water. This aqueduct is 600 feet long.

The next point for our consideration is the *lock*. This ingenious arrangement is intended to overcome the difficulties

attendant upon conveying a canal over unlevel ground, so that the navigation shall be continuous. There are other contrivances besides the lock for attaining this object; but for ordinary purposes the lock is the most desirable. Before the invention of the lock, inclined planes were made use of for enabling the barges to pass from one level to another, and it was only in 1460 that locks were first employed upon canals. They were used in the Canal of Martezana, in Italy.

A lock consists of a portion of the canal fitted at each end with folding doors or gates, which when closed prevent the passage of the water through them, except when a valve or sluice, which is constructed in them, is opened. By means of these gates and valves the water in the intermediate portion can be brought to the same level with that either in the upper or lower section of the canal, and a barge enclosed between them will *descend* with the descent of the water from the upper to the lower section, or will *ascend* with the rise of the water from the lower to the upper section. The upper gates are called the *sluice*-gates, and the lower the *flood*-gates. The area of the lock should never be allowed to exceed what is actually required for the navigation, because every time a lock is emptied the enclosed mass of water descends to a lower level, and causes, by so much, a demand upon the source of supply at the higher levels. It is therefore desirable to reduce this mass of water as much as possible.

The difference of level upon the opposite ends of one lock should be kept, as nearly as possible, to 8 feet. If more than this, the strain caused by the water-pressure becomes excessive, and it is better to subdivide the height by a second lock.

The depth of a lock must be such that a barge navigating the lower section can float freely into it when the sluice-gates are closed and the flood-gates open, and the height of the flood-gates must be such that when closed, and the water admitted into the lock from the upper level, it shall not overflow them. The position of a lock is just at the termination of a level where the ground begins to fall. It is for every reason desirable to construct a lock of masonry, so that the wash of the water, caused by opening the sluices, shall not augment its capacity. Sometimes, when the traffic is heavy, as upon the Regent's Canal, in London, the locks are made double—that is, side by side, separated by a strong pier of masonry—and a flood-gate or valve is placed in this pier, by which communication can be made between the two locks. By this arrangement a saving of water is frequently effected, as, instead of allowing an entire lockful of water to pass into the lower section, half of it can be passed into the adjoining lock, should that happen to be empty at the time. Great care is needed in constructing the retaining walls and piers of locks. As a rule, the thickness of a wall intended to support the lateral pressure of water should not be less than half the height of the water which presses against it. The surface of the masonry should be set in cement, and the bonding should be arranged so as best to withstand the thrust of the closed gates.

The gates of locks are usually constructed of timber, although in some instances they are of iron. If of timber, they consist of two strong upright posts, the inner being called the *quoin*, or *hanging* post, and the outer the *mitre*, or *shutting* post. These are framed together with several horizontal rails or cross-bars, and the whole consolidated by braces *closely* laid, and placed either vertically or diagonally, the dip of the diagonal being *downwards* from the hanging post. By this means the stress is transferred to that post. The valves or sluices are small doors sliding vertically over orifices left in the framework of the gate, and usually raised and lowered by a rack and pinion worked from above. The hanging of the gates demands great care. They must be made to fit so accurately both at the sides and middle, as that very little, if any, water can percolate through when they are closed. Their lower centre moves in an iron plate leaded into the stone-work, while the upper is supported by a strap keyed or bolted to attachments let into the upper courses of masonry. The strap, by the action of the keys or bolts, can be altered in its position, to allow for wear in the centre, and for other purposes, such as the ready unhinging of the gate for repairs. In Fig. 7 is shown a plan of the ordinary arrangement of hanging; C being the centre of the gate G, S the strap passing round the centre, and P the iron plate let into the masonry. As it would be impracticable to allow the gates to rest upon the ground, owing to the friction which would result,

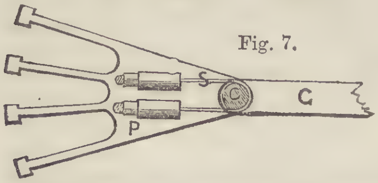


Fig. 7.

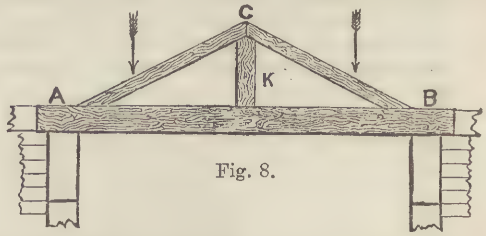


Fig. 8.

and as, nevertheless, any space which existed under the gates when closed would be the cause of considerable leakage, when the level of the water is higher on the resisting side, their bases are made to close against a timber sill, called a *mitre sill*, the angle of which must agree accurately with that at which the gates are intended to remain when shut. This sill is partly embedded into the masonry on the bottom of the lock, and is framed as shown in Fig. 8. The arrows indicate the direction of thrust.

The piece A B runs transversely across the lock, the ends being worked into the side walls under the hollow quoins. The angle A C B, which, as we have stated, must correspond with the angle at which the gates stand when shut, varies according to the views held by engineers. It must certainly vary with the size of the gates—that is, with the pressure of the water. The larger the gates the more acute the angle should be. The reason for this is obvious: since if the gates are small, the pressure of water, being less, would scarcely ensure the efficient closing of the gates, if the angle be too acute; whereas if the gates are large, the great pressure of water would act injuriously against the bearings of the gates, if the gates closed at too obtuse an angle. The nearest approach to a rule we can lay down is, that when the head of water is from 5 feet to 9 feet, the length of the king-post K (Fig. 8) shall be one-fifth of the length of the opening of the lock; if the head be less than 5 feet, the king-post may be one-sixth of the opening.

Owing to the fact that the flood-gates are sometimes partly submerged, and sometimes entirely out of the water, their weight will vary. Long levers are therefore fixed to them, to facilitate opening and shutting them, at the same time being made very heavy to balance them. If the gates are very large and very heavy, the balance levers are dispensed with, and the gates are furnished with small iron wheels, upon which they rest, and which run on iron rails curved to the arc they describe. The gates are in this case opened and closed by means of chains attached to them.

SEATS OF INDUSTRY.—VII.

GLASGOW.—I.

BY WILLIAM WATT WEBSTER.

GLASGOW is by far the largest town in Scotland, and in point of wealth and population ranks third among the cities of the United Kingdom. It is at once one of the most ancient and one of the most flourishing centres of commercial and manufacturing enterprise in Britain. All the principal phases through which trade and manufactures have passed since the dawn of the modern industrial era are illustrated in the story of this city. Entering early on a commercial and manufacturing career, Glasgow has steadily maintained the foremost place among the industrial towns of Scotland; and every great discovery or improvement in the methods of production and transit has, quickly after its introduction, been made to contribute to its prosperity.

The spot now occupied by Glasgow was the site of a Roman station, and the remains of a Roman camp are still to be seen at a place called "Camphill," two miles to the south of the city. Glasgow formed part of the province of Valentia, which was bounded on the north by the wall of Antoninus, that ex-

tended from the Frith of Forth to the Frith of Clyde, and it is believed that it continued in the possession of the Romans till about the year 426, or shortly before the time when they finally abandoned the island. There is a tradition that the site on which the cathedral of Glasgow stands was consecrated as a burying-ground by St. Ninian of Galloway, as early as the beginning of the fifth century; and historians are agreed that a religious house or see was established there by St. Mungo, or, as he was also styled, St. Kentigern, about the year 560. The city, undoubtedly, had its origin in a religious establishment, and St. Mungo is its reputed founder. Several fathers of the Roman Catholic Church have recounted the fabulous achievements of this holy ecclesiastic, and those portions of the legendary story of his life which explain the arms and motto of the city with which his name has been associated for so many centuries may fitly find a place in this paper. The arms of Glasgow consist of a tree, with a bird perched in its boughs; on one side is a salmon with a ring in its mouth, and on the other a bell. The tree is said to commemorate a miracle which St. Kentigern performed at Culross, when he broke a frozen bough from a hazel, and kindled it into flame by simply making the sign of the cross over it. Regarding the ring and the fish, an equally extraordinary story is told in the monkish legends. The queen of Cadyow having lost a ring presented to her by her lord, who threatened to put her to death if it could not be found, went to St. Kentigern in great distress, and besought him to put forth his supernatural power to recover the missing jewel. After he had concluded his devotions, the saint went forth to walk along the banks of the river Clyde, as his custom was, and seeing the fishermen plying their vocation, he asked them to bring him the first fish that was caught. It is hardly necessary to add that the ring was found in the mouth of the fish, and that the lady was saved from the fate which threatened her. The bell is the effigy of a famous bell that St. Kentigern brought from Rome, which was preserved in Glasgow till the Reformation, if not to a more recent period. There is no miraculous story associated with the bell. It is otherwise, however, with the motto :—"Let Glasgow flourish by the preaching of the word." Having incurred the hostility of the heathen chief of Cumbria, St. Kentigern was compelled to fly from the newly-organised settlement at Glasgow, and seek refuge in Wales, where he abode for some years, and founded the bishopric still called after his disciple, St. Asaph. When his enemy died, the holy man returned to the scene of his former labours, and was welcomed back by a great crowd. Beginning to preach the Gospel to the thronging multitude, St. Kentigern soon found that it was impossible, owing to the flatness of the ground, to make himself heard, except by those in his immediate neighbourhood. This acoustic defect, however, was soon remedied; for, lo! on a sudden, the plain on which he stood was transformed into a hillock, from whence he was both seen and heard. According to the legends, St. Kentigern received the name of Mungo from his spiritual father St. Servan, the Culdee of the Inch of Lochleven, whose favourite disciple he was; and the word *Mungo* or *Mungah* signifies in the Norwegian language "dear friend." For five hundred years after the death of St. Mungo, which occurred in 601, the history of Glasgow is almost a blank. The people who inhabited the valley of the Clyde are believed to have acquired a certain degree of civilisation from being brought into close contact with the Romans, and the "Kingdom of Strathclyde," which was founded after the departure of the Romans, was intact at the time when Bede, the historian, died in 734. One of the princes of the Strathclyde dynasty conferred a grant of lands on the religious house which St. Mungo established; but the fraternity were robbed and maltreated, alternately by Picts, Scots, Saxons, and Danes. In 1115, David, Prince of Cumberland, repaired the devastations of St. Mungo's settlement; and in 1129, four years subsequent to his accession to the throne of Scotland, this pious and munificent sovereign appointed his preceptor, John, commonly called Achaius, to be bishop of the see. A few years later the pile was rebuilt, and on its consecration David I., in addition to his previous gifts, conferred on the community of St. Mungo the valuable lands of Partick, which are now in the possession of the University of Glasgow. The liberality which this sovereign displayed towards the Church gained him the title of Saint, and caused one of his successors on the throne, James V., to grumble that he had been "ane sair sanct for the croon." There are no means of determining whether Glasgow had at this period attained the dimensions of a town, but the nucleus round which the city has gathered and grown was now formed. The claim of King David I. to be considered the re-founder of the city, is at least as good as that by which St. Mungo holds the title of founder. In 1181 the building erected by David I. was replaced by the present pile; and in 1190, King William the Lion raised Glasgow to the dignity of a royal burgh, with the privilege of an annual fair, which is still held. For the next century and a half, however, Glasgow remained a small town of some fifteen hundred inhabitants. The first bridge across the Clyde was built by Bishop Rae, about the year 1345; and in 1451 Bishop Turnbull, on the authority of a bull obtained from Pope Nicholas V., established the University. But although the latter exercised almost as important an influence on the early fortunes of the city as the erection of the cathedral, yet as late as 1550 Glasgow was only the eleventh among the towns of Scotland.

Commercial enterprise began to manifest itself in Glasgow at a comparatively early period. John M'Ure, *alias* Campbell, "Clerk to the Registration of Seisins and other Evidents for the District of Glasgow," published a history of the city in 1736, when he was in his seventy-ninth year, from which we learn that "the first promoter and propagator" of the trade of the place was William Elphinstone, a cadet of the noble family of that name, and father of Bishop Elphinstone, the founder of King's College and University at Aberdeen. This trading worthy acquired wealth and fame about the year 1420, by curing salmon and herrings, and exporting them to France and other Continental countries, bringing back brandy, wine, and salt in exchange. M'Ure mentions as the "second promoter and propagator" of trade, Archibald Lyon, a younger son of Lord Glamis, who was brought to Glasgow near the close of the fifteenth century by Archbishop Dunbar, and who became a great merchant, and "undertook great adventures and voyages in trading to Poland, France, and Holland." The success of this high-born merchant is attested by the extent of the possessions he acquired in and around Glasgow. In the inventory of his wealth the following items occur :—"A great lodging for himself and family upon the south side of the Gallowgate Street; four closes of houses and forty-four shops, high and low, on the south side of the Gallowgate; and a part of the left side of the Saltmarket." But the foreign trade of Glasgow at this time must have been trifling, although about the year 1600 the prosperity of the foreign merchants excited the jealousy of the tradesmen, who wished to share the advantages enjoyed by the former; and the disputes between them led to the establishment of a guildery in 1605, for regulating and maintaining the limits of trade and commerce, having at its head a dean, who was to be "a merchant, a merchant sailor, and a merchant venturer." The effect of the regulations instituted by this guildery was, that none but guild brethren were in future permitted to trade or traffic in Glasgow. An interesting account of Glasgow half a century later is to be found in a report on the revenue from the excise and customs of Scotland, dated 1651. "With the exception of the coligeners," says Commissioner Tucker, "all the inhabitants are traders: some to Ireland, with small smiddy coals, in open boats from four to ten tons, from whence they bring hoops, rungs, barrel-staves, meal, oats, and butter; some to France, with plaiding, coals, and herrings, from whence the return is salt, pepper, raisins, and prunes; some to Norway for timber. There have likewise been some who have ventured as far as Barbadoes. . . . The mercantile genius of the people is strong, if they were not checked and kept under by the shallowness of the river, every day more and more increasing and filling up, so that no vessel of any burden can come up nearer the town than fourteen miles, where they must unload and send up their timber on rafts, and all other commodities by three or four tons of goods at a time, in small cobbles or boats, of three, four, or five, and none above six tons a boat. . . There are twelve vessels belonging to the port, none of which come up to the town—total 957 tons." The most notable among the merchants of Glasgow from 1651 to 1707 were Walter Gibson and John Anderson. The former had dealings with France, Spain, Norway, and Virginia, and was the first merchant who brought iron to Glasgow, while the latter is celebrated as the first merchant who imported wine direct into the city.

PRACTICAL PERSPECTIVE.—V.

FIG. 24.—The subject of this lesson is a cross, of a similar character to that shown in Figs. 20, 21; but in the present study the object is lying on the ground with the ends of its cross-arm parallel to the picture-plane.

It will be remembered that Fig. 20 was shown to be contained in a rectangle, and this plan is again adopted in the present lesson.

From A, the point immediately under the centre of the and G D will be the real length of the arms, and F G their width. From F and G draw lines to the centre of the picture, cutting D′ E in H, I. F H I G is the plan of the arm.

But the timbers of which the cross is made are of equal thickness, and therefore F G is not only the width of the arm but of the upright stem of the cross; and further, the arms project horizontally from the stem, precisely as much as the stem projects above them, and the space cut out of the corner of the containing rectangle is therefore a square, the side of which is B F. Therefore, from F and G draw lines to the point

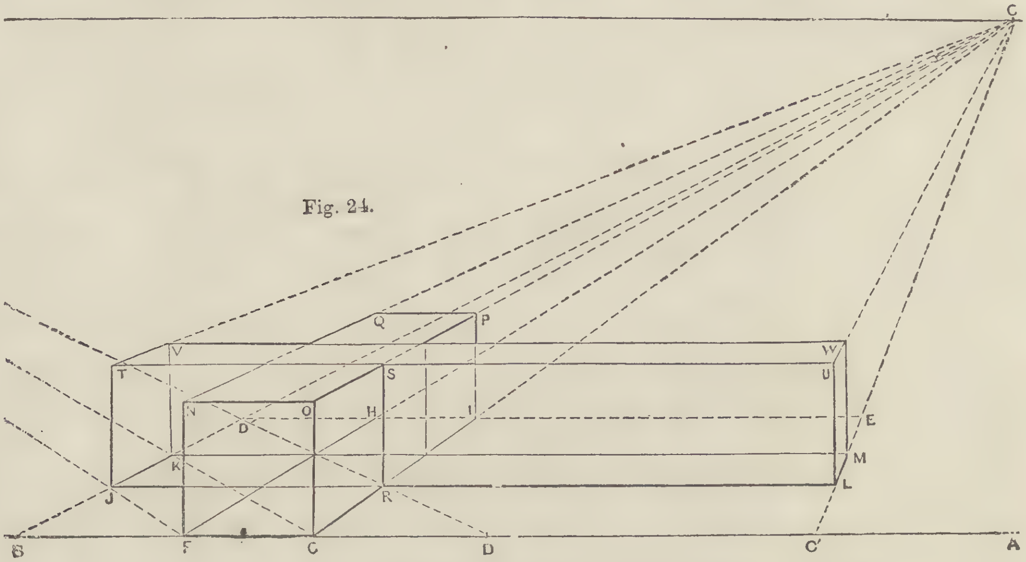


Fig. 24.

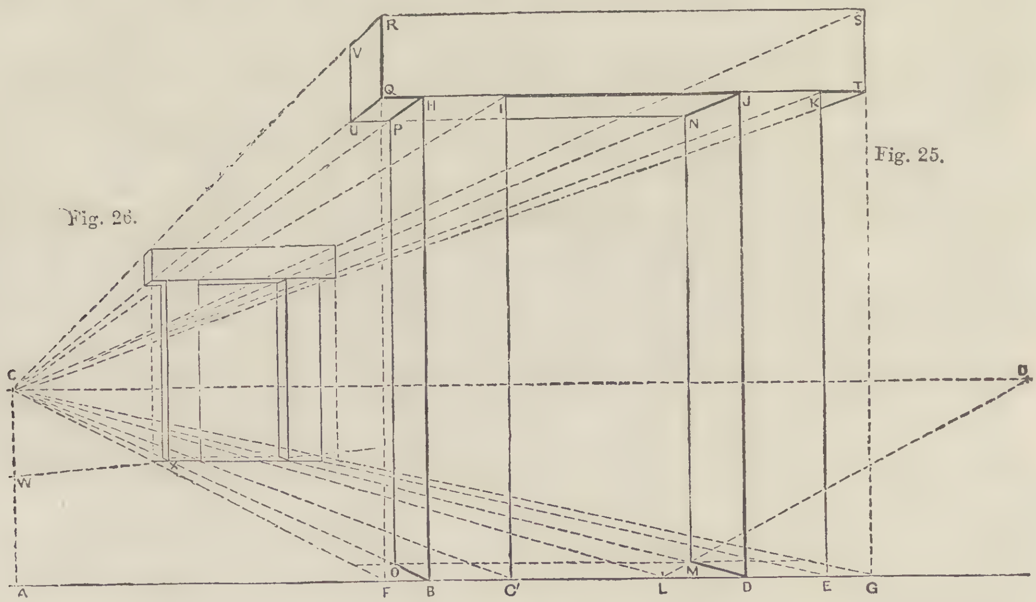


Fig. 25.

Fig. 26.

picture, mark off A B equal to the distance of the top of the cross on the left of the spectator; and from B set off towards A the distance B C′, representing the entire height of the cross.

From B and C′ draw lines to the centre of the picture.

From B set off B D, representing the width of the containing rectangle. Draw a line from D to the point of distance (the point of distance is not shown in this figure), which will cut the line drawn from B to the centre of the picture in D′.

At D′ draw a horizontal line, cutting C′ C in E, which will complete the perspective representation of the rectangle when lying on the ground.

Now between B and D set off the lengths B F, F G; then B F of distance, cutting the line drawn from B to the centre of the picture in J and K. Draw J L and K M, and these will complete the plan of the cross.

Now on F G construct a square, F G N O, which will be the elevation of the end of the arm.

From N and O draw lines to the centre of the picture.

At I draw a perpendicular, cutting O C in P, and at P draw the horizontal P Q, which will complete the solid rendering of the arm.

The line drawn from G to the centre of the picture cuts J L in R; at R erect a perpendicular, cutting O C in S. At J and L erect perpendiculars. Through S draw a horizontal, meeting

the perpendiculars J and L in T and U. At K and M erect perpendiculars. From T and U draw lines to the centre of the picture, cutting the perpendiculars K and M in V and W. Join V W by a horizontal, and this will complete the figure. Such lines as would be visible in the object are then to be strengthened.

Fig. 25.—The subject of this lesson is a simple doorway, consisting of two uprights, and a horizontal resting across them.

Having drawn the picture and horizontal line, and having fixed the centre of the picture and the point of distance,* mark off the distances A B, B C′, C′ D, and D E. These will give the positions of the uprights.

From B set off B F, and from E set off E G.

These spaces represent the length which the horizontal projects beyond the uprights. These would not be absolutely necessary if the one figure in the foreground only were to be drawn, but as a distant figure is to be added, it is advisable that they should be marked at the present stage.

Draw the perpendiculars B, C′, D, E; join H I and J K, and from the upper and lower extremities of the perpendiculars draw lines to the centre of the picture.

From D set off D L equal to the width of the receding side of the upright, and from L draw a line to the point of distance, cutting the line D in M. At M draw a perpendicular, meeting J in N, which will complete the view of one of the uprights. Draw a horizontal line through M, cutting the line drawn from B to the centre of the picture in O; also a horizontal line from N, cutting H in P. Then the perpendicular O P will complete the perspective projection of the second upright.

Produce the horizontal H K, and terminate it by perpendiculars from F and G, which will give the ends Q R, S T of the horizontal. From Q and R draw lines to the centre of the picture. Produce N P to meet Q in U, and from U draw the perpendicular U V. Q R V U will be the view of the end of the horizontal, and the projection will then be finished.

Fig. 26 represents the same object at a distance back in the picture. Draw lines from F and G to the centre of the picture, and having set off from B on the picture-line (at a point not shown in the figure) the distance which the figure is supposed to be from the picture-plane, draw a line from such point to the point of distance. (The position of this line shown in the figure is lettered W.)

The line W, intersecting B in X, will give the required position. Through X draw a horizontal, and this, intersecting all the lines drawn from the points in the foreground, will give the places of the perpendiculars in the distance, and the rest of the construction will be readily understood from the diagram.

* The student is advised to fix these at different distances from those in the figure. This will prevent his absolutely *copying* the diagrams.

Fig. 27.—In this figure the two objects are placed in a line, so that their faces are at right angles to the picture-plane.

Having fixed F as the distance of the objects on the left of the spectator, set off from it F L, equal to the breadth of the side of the object. This length is similar to L D in Fig. 25, which, seen perspectively, becomes D M.

From F and L draw lines to the centre of the picture; and it is in this track that the object travels as it recedes into the distance. From F mark off F B, C′, D, E, G, as in the previous figure, and from each of these points, excepting F, draw lines to the point of distance, intersecting F C in B′, *c*, D′ E, and *e*. At F erect a perpendicular, and mark on it the heights Q and R. From Q and R draw lines to the centre of the picture.

Now from B′, *c*, D′, and E erect perpendiculars to meet Q in H, I, J, and L′, and another from *e* will give S T.

At Q R draw horizontals, and at L erect a perpendicular. This will give the square Q R V U, representing the end of the horizontal; and from U draw a line to the centre of the picture.

From B′ draw a horizontal, cutting L C in O, and at H draw a horizontal, cutting U C in P. Join O P by a perpendicular.

At D′ draw a horizontal, cutting L C in W. At J draw a horizontal, cutting U C in N. Join W N by a perpendicular, and this will complete the view of the object.

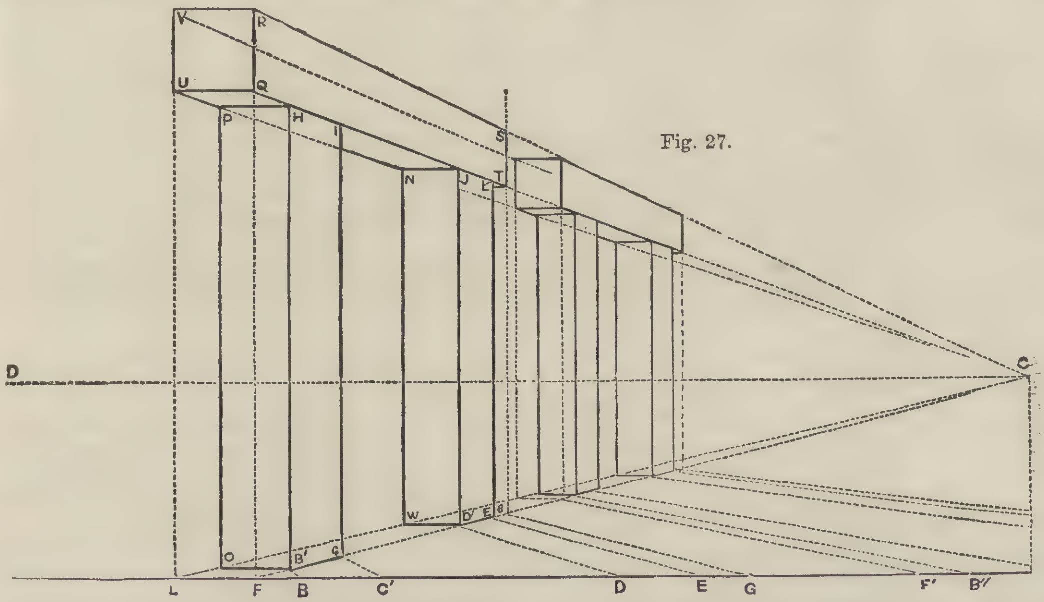


Fig. 27.

In commencing the second figure, set off from G the length G F′, equal to the distance of the second object beyond the first. From F′ set off B″, and all the other points as in the first figure.

From these points draw lines to the point of distance, intersecting the line drawn from F to the centre of the picture, as in Fig. 25, and from these raise perpendiculars. Then the lines drawn from Q, R, U, V to the centre of the picture will give the necessary points and lines for the horizontal, and so complete the figure.

WEAPONS OF WAR.—VII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

GREAT GUNS AND THEIR PROJECTILES.

We now enter upon another stage of our subject. We have dealt hitherto with hand-weapons—weapons to be wielded by individual combatants, and comprised within the term "small-arms." We have traced, however imperfectly, the gradual development of weapons of this sort, through the stages of swords, spears, and pikes, of arrows, javelins, and missile weapons, up to the Needle-gun, the Chassepot, the Snider, and the Martini-Henry.

We must now turn to great guns, and consider the principal types of cannon in use in this and foreign countries.

The same principles which have governed the successive developments of small arms have applied to cannon, with some

modifications or additions. The power of being able to reach your enemy at a continually increasing distance, of being able to strike him with greater and greater certainty, of being able to do him more and more harm, and of accomplishing all this with the minimum of inconvenience and difficulty to oneself—this is the problem which for several centuries the artillerist has set himself to solve; and these conditions may be said to apply to all classes of ordnance, heavy and light. But the conditions imposed in the two cases are very different. In the case of the light gun, the object generally is to destroy men; in the case of the heavy gun, although the ultimate object is to carry destruction and dismay among the *personnel* of your enemy, that object can generally only be attained through the destruction of his *matériel*. Again, while there is practically hardly any limit to the size of the heavy gun, except the endurance of the weapon itself, the field-gun has to be of a weight no greater than will permit of its easy and rapid transport on a campaign, and from one part of a field to another. Lieut. Hime, R.A., in an interesting paper on Field Artillery, in the "Proceedings of the Royal Artillery Institution," observes that "motion is the essential difference between the two great branches of the artillery service, being as necessarily included in the conception of field artillery, as it is necessarily excluded from the notion of garrison artillery. The latter is the artillery of rest, the former is the artillery of motion; and an immovable field artillery is a contradiction in terms." Marshal Marmont used to say, "Le premier mérite de l'artillerie, après la bravourie des canoniers et la justesse du tir, c'est la mobilité." It would seem that this proposition might be fitly reversed—for no amount of gallantry, no amount of accuracy, would compensate for an absence of mobility. Gustavus Adolphus, at any rate, acted upon this principle, for, as Lieut. Hime tells us, he resolved at the commencement of the Thirty Years' War to increase the mobility of his field artillery "at all hazards," and he actually took the extraordinary step of introducing *leather* guns of great mobility, but of inferior accuracy as compared with the iron guns then in vogue. These leather guns did good service before they dropped into disuse.

Therefore, it is important to insist upon this fundamental distinction between field and garrison (or naval) artillery—the necessary mobility of the former.

But it would not do to divide artillery into two great groups, separated by a hard and fast line. On the contrary—while in the one direction field artillery shades off into mountain artillery, and garrison artillery developes into the monster turret guns, which are moved on huge turn-tables within the cupola or turret—the two classes of field and garrison meet on common ground, and almost imperceptibly shade off one into the other in guns of position and siege guns.

If we were required to classify artillery at all, we should adopt some such distribution as the following:—

1. Mountain guns.
2. Field guns { (a) Horse artillery. (b) Field artillery.
3. Guns of position.
4. Siege guns.
5. Garrison and broadside guns.
6. Turret guns.

Most of these classes admit of further subdivision—for there are mortars, howitzers, carronades, shell-guns, and guns proper; there are also smooth-bore and rifled guns. It is evident, therefore, that an exhaustive treatment of every detail of this large subject is impossible within the limits of the present series of papers. We shall therefore not attempt to deal with each sub-division or class of weapons in detail, but will take the more salient points of the different systems in the order in which they occur to us.

Until some twelve years ago nearly all artillery consisted of smooth-bores. Rifled guns of great variety and ingenuity of design have been prepared by sanguine inventors, and many of them have been experimented with. But the guns of the English service, like those of other nations, remained smooth-bores. It may be supposed that it is unnecessary to speak of smooth-bores now—that their day has gone by so completely as to invest them with no other than an antiquarian interest. This is not the case; it must take many years before smooth-bores disappear from our service; for some purposes—as for the flank defence of ditches, where range and accuracy are of no importance, while a high velocity of projectile is of very great importance—smooth-bores will probably always be retained. Again, at this moment there does not exist a single rifled mortar in the British service; while the Americans scarcely use any other than smooth-bore guns, even for their first-class armaments. So that, although the day of rifled guns dawned some dozen years ago, that of smooth-bores has not yet set.

A smooth-bore gun is merely a hollow tube of iron, or steel, or bronze, or other suitable material, intended to project a spherical projectile. The expression "smooth-bore" has reference, of course, to the unrifled condition of the bore.

The largest smooth-bore gun in the British service prior to 1858 was the 68-pounder, so-called because the solid spherical shot which was discharged from it weighed 68 pounds. The gun itself weighed 95 cwt.,* and it fired a charge of 16 pounds of powder. It is interesting to compare this, the biggest English gun of 1858,† with the biggest English gun of 1871. The latter is a 700-pounder, its weight is 35 tons, or 700 cwt., or more than ten times that of the 68-pounder. The charge of the 35-ton gun will be 113 lb. or 120 lb of powder. Before we come to speak more particularly of the 35-ton gun, we have a great deal of ground to cover. But it seemed interesting to show by this contrast the strides which have been made in twelve years. All the heavy English smooth-bore guns were made of cast-iron—about as bad a material as could well be employed for ordnance, because of its comparatively low resisting power and its liability to yield suddenly, and without warning when it did yield, and thus to cause what artillerymen most dread—an explosive burst. However, for firing the comparatively low charges then in vogue, the cast-iron was fairly suitable. It is true that the annals of our artillery are darkened by the record of many disasters due to the bursting of these guns; but it is probable that, had it not been for the introduction of rifled artillery, and the new conditions imposed upon the gunmaker, cast-iron would have continued to be employed for several years to come.

Where great lightness was required—as for field-guns—bronze or "gun-metal" was employed. Bronze is an alloy of copper and tin in the proportion of about 11 to 1. The advantages of this material are its lightness, its non-liability to explosive rupture, its value as old metal when the gun is worn out, and the facilities of production. On the other hand, the softness of bronze has always constituted an objection to its use for artillery; this softness was apt to cause the guns to become bulged and unserviceable with long-continued firing, and "drooping at the muzzle" was a complaint to which bronze guns were considered to have been especially liable.

The smooth-bore field-guns of the British service were generally 9-pounder guns and 24-pounder howitzers for field batteries, and 6-pounder guns and 12-pounder howitzers for horse artillery. The howitzers differed from the guns in throwing heavier projectiles with greatly reduced charges. While the relation of the charge to the projectiles in the guns was about as 1 to 3½ or 4, in the howitzers the relation was about as 1 to 9 or 10. This reduction of charge enabled the howitzers, although firing far heavier projectiles, to be made thinner and shorter than other guns, which they thus did not exceed in weight—the 9-pounder gun and the 24-pounder howitzer weighing each about 13 cwt., the 6-pounder gun and 12-pounder howitzer weighing each about 6 cwt. The mode of carrying these pieces, as well as that of carrying and mounting guns generally, will be treated in a separate paper.

Between the field-guns and the 68-pounder before mentioned, there were a number of guns intended for a variety of purposes. The designation of these guns was as follows:—56-pounder, 42-pounder, 32-pounder, 24-pounder, 18-pounder, and 12-pounder. The 56-pounder and 42-pounder are fast becoming obsolete, but the other guns still exist in the service in considerable numbers. The whole of these guns were made of a weight and strength which permitted of the use of solid shot or shell, with relatively heavy charges of powder. There were, however, guns intended specially for projecting shell with low charges; these were the 10-inch and 8-inch shell-guns and howitzers.‡ There were also

* There were some of 112 cwt.

† A few 150-pounder and 100-pounder smooth-bore guns were subsequently introduced.

‡ The number of inches whence these guns have their designation, refers to the diameter of the bore.

pieces designed for projecting either shell or shot with very low charges; these were called carronades. The charges for shell-guns and howitzers varied from about $\frac{1}{6}$th to $\frac{1}{12}$th the weight of the heaviest projectile; the charges for all carronades being fixed at about $\frac{1}{12}$th the weight of the shot.

Originally shells were not projected from guns and howitzers at all; they were thrown from mortars. A mortar is a short piece for throwing shells at an angle of 45° into an enemy's position; and for the bombardment of a town, or any large area, this "vertical fire," as it is called, is terribly effective. Indeed, it would be terribly effective against all positions, if sufficient accuracy could be obtained to insure hitting the object aimed at. But the comparative inaccuracy of vertical fire—the shell describing a roundabout path to arrive at its object, and being therefore for a longer time under disturbing influences than the shell from a gun—has hitherto constituted a formidable objection to its extended use. It will be easily understood that the effect of a shell falling on to the deck of a ship would be tremendous; but a ship, especially a ship in motion, presents such a small and difficult object for attack, as to entail an immense waste of ammunition in trying to hit it. The same objection does not apply to the employment of mortars against large entrenched positions, towns, etc. Attempts are now being made to introduce rifled mortars, by which the irregularities of vertical fire may be, if not removed, at least diminished, while in range and general power such pieces would be vastly more effective than smooth-bore mortars. An interesting development of mortar-fire was suggested by Mr. Mallet, C.E., in 1858. Mr. Mallet proposed to throw enormous shells, 36 inches in diameter, weighing 2,481 lb., and containing each a bursting charge of 480 lb. (equal to nearly five barrels) of powder. Thus, the total weight of each shell filled was about $1\frac{1}{4}$ tons. Mr. Mallet also proposed a mortar of suitable proportions to project these monster shells. The proposition attracted a good deal of attention, and by Lord Palmerston's order two of the mortars and a number of the shells were supplied by Mr. Mallet for experiment. Both mortars and shells may be seen by visitors to Woolwich Arsenal, where they form objects of curiosity and interest. Mortars are designated by their calibres in inches. There are five sizes in the British service—viz., 13-inch, 10-inch, 8-inch, $5\frac{1}{2}$-inch, and $4\frac{2}{5}$-inch.

We see, then, that there existed smooth-bore ordnance suitable for throwing projectiles of all sorts, and of delivering a "horizontal" or a "vertical" fire; that these pieces were made of cast-iron, except those intended for field-guns, which, on account mainly of their greater lightness, were made of bronze. But a gun, after all, is only a means to the end. It is an instrument merely for throwing projectiles, with more or less of range and accuracy, more or less of destructive effect. We will therefore pass to the projectiles which were used with these pieces, before going on to state in what manner the range and accuracy of the smooth-bore guns has been improved upon, and how artillery has attained to the pitch of destructive power which it has now reached. We will therefore proceed to treat of the different classes of projectiles which are fired from smooth bore guns.

With the exception of such projectiles as were intended to break up at the muzzle and produce an immediate scattering effect, or projectiles which, like the ground light ball, were not required to have any special accuracy, the projectiles thrown from smooth-bore guns were all spherical, that form being the one which naturally, in the absence of rifling, could be thrown with more certainty and accuracy, and to a greater distance than any other. The two main classes of projectiles are shot and shell. There is a third class of incendiary and miscellaneous projectiles which must not pass unnoticed. The varieties of each class are much more numerous than persons generally suppose. Thus, the word "shot" generally conveys but one impression to the mind of the non-professional. It almost inevitably suggests the solid "round shot" of iron. But, in addition to round shot, there are solid steel shot, and solid chilled iron shot, hollow shot, case-shot, and grape-shot. The solid shot is the simplest and most primitive form of projectile, the object with which it is employed being, of course, to kill or disable an enemy, or to batter down or penetrate his defences. When defences were of brick and stone, or wood, or when troops fought in the open, it sufficed to make the shot of cast-iron; but when armour-plated defences came into vogue, it was necessary to use some other material. Accordingly, steel shot were introduced for use with the larger smooth-bore guns, with which some of our ships were still armed. The great cost of steel, however, and the success which had attended the employment of the famous Palliser "chilled" projectiles (of which more particular mention will be made hereafter), induced the authorities to give a trial to some solid spherical "chilled" iron projectiles, some of which still exist.* The chilled *spherical* projectiles were far from satisfactory. Their form was unsuitable to the brittle material, but it was thought that they were somewhat more effective than ordinary cast-iron, and they were not more expensive. The fact is, that no spherical shot are very effective against thick armour-plates—at least, any effect which may be accomplished can only be obtained at a disproportionate expenditure of power, and then only at very short ranges. No smooth-bore gun can compare with a rifled gun for penetration; because with the rifled projectile, if the weight of shot be equal to that of the sphere, the diameter will be less, and if the diameter be equal, the weight will be more; and we thus have either less work to do, and equal power to do it, or equal work to do, and more power to do it. To this must be added that the pointed form of head is far more favourable to penetration than is the hemispherical surface with which the spherical shot strikes the plate. Hollow shot were used by the navy against wooden ships at short ranges, in order to produce a greater splintering effect, and to carry more fragments into the vessel. They could not be used effectively at long ranges on account of their lightness. Of late years empty shells have been used as hollow shot when required; but at one time hollow shot constituted a separate projectile.

An application of small solid shot, weighing 1 lb. each, must not be omitted. They are thrown sometimes from a mortar, in charges of one hundred shot. The shot are piled loose in the mortar over the powder, a piece of wood being placed between the powder and shot; and against crowds of men huddled together, or a fleet of small boats, these *pierrier* † charges of pound-shot are very useful. Case-shot is used for firing at troops in masses at short ranges. They consist of cylindrical iron cases, filled with balls. The case is broken by the discharge, and its contents are driven forward in a conical shower to a distance of from 300 to 400 yards from the muzzle of the gun. When cavalry are charging home, or when troops present themselves within the range indicated, case-shot are terribly effective, and many a gallant charge has been checked, and many a gallant column thrown into disorder and panic by a well-directed discharge of these destructive missiles.

Grape-shot is intended for use on much the same sort of occasions as would be selected for the use of case, except that, being made up with heavier balls, its range is somewhat greater. It was also useful for cutting and destroying the rigging of ships in naval actions. Originally, grape consisted of a canvas bag filled with balls, piled round an iron spindle through the centre of the bag, the bag being drawn together between the balls, or "quilted" by a strong line. In this form the grape somewhat resembled a bunch of grapes—whence its name. For several years the quilted grape has been superseded by grape of a pattern known as the "Caffin" grape. This pattern consists of four horizontal iron plates, connected by a spindle through the centre, and having three tiers of shot arranged between the plates. The advantages of this pattern are, that it is less perishable than the old-fashioned grape, the bag and cord of which were liable to rot and fall to pieces; that it is more portable, as it can be carried in pieces, and put together when required; and that the parts are interchangeable. During the past two or three years the manufacture of grape has ceased, it being considered that case-shot will answer all the purpose.

This completes the list of shot for smooth-bore guns. We will give in our next lesson descriptions of the various shells and other projectiles used with this class of ordnance.

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* We reserve for the present such remarks as suggest themselves in connection with chilled projectiles, until we come to speak of the Palliser shot and shell.

† From the French word *pierre*, a stone—from a number of stones having been in early days fired in this way instead of shot.

TECHNICAL DRAWING.—XXV.

DRAWING FROM ROUGH SKETCHES (*continued*).

FIG. 239 is half the elevation, and Fig. 240 is a vertical section of an equilibrium valve. Valves of this description are used in engines of large dimensions, such as those used for pumping in Cornwall.

In these valves a large extent of opening for the passage of steam is given with very little traverse, whilst very little power is required to work the valve.

In the example here shown, A is the fixed seat, made of cast-iron or brass, which forms a part of, or is secured to, the valve-chamber. B is a bell-shaped valve-piece, also of brass, moved by a rod, C.

The contact of the valve with its seat takes place at two places, *a* and *b*, which are formed into accurate conical surfaces, the one, *a*, being internal, and the other, *b*, external.

When the valve is closed, these surfaces coincide with similar ones on the seat, and when it is lifted, as shown in Fig. 240, two annular openings are simultaneously formed; thus giving a double ingress or egress, as the case may be, to the steam, which enters at, or issues through, the upper opening, *a*, through the central part, D, formed in the valve-piece, B.

It is hoped that these measurements having been given, the student will be enabled to complete the figure, and also to draw the section.

The two drawings may be placed next to each other, as in our example, in which case all the vertical measurements for the exterior of the section may be projected by simply carrying out the horizontal lines. Or the section may be placed under the elevation, in which case the measurements for the widths will be obtained by drawing perpendiculars from the widths as set off in the elevation. These two examples should be drawn to the scale of ½ an inch to an inch.

PROJECTION AND PENETRATIONS (*continued*).

It is now deemed desirable to give the student another course of lessons in projection, and for this purpose the first subject selected is a bent cylinder.

Fig. 241.—Let A B, C D represent a quarter of a cylindrical ring, the centre of which is at O.

Now if this quarter-round were cut across the middle by a plane radiating directly from the centre—viz., O O′—and the upper half were rotated on a pivot at E, the cylinder would take the bent form represented in the figure, for D would be moved to D′, and B to B′.

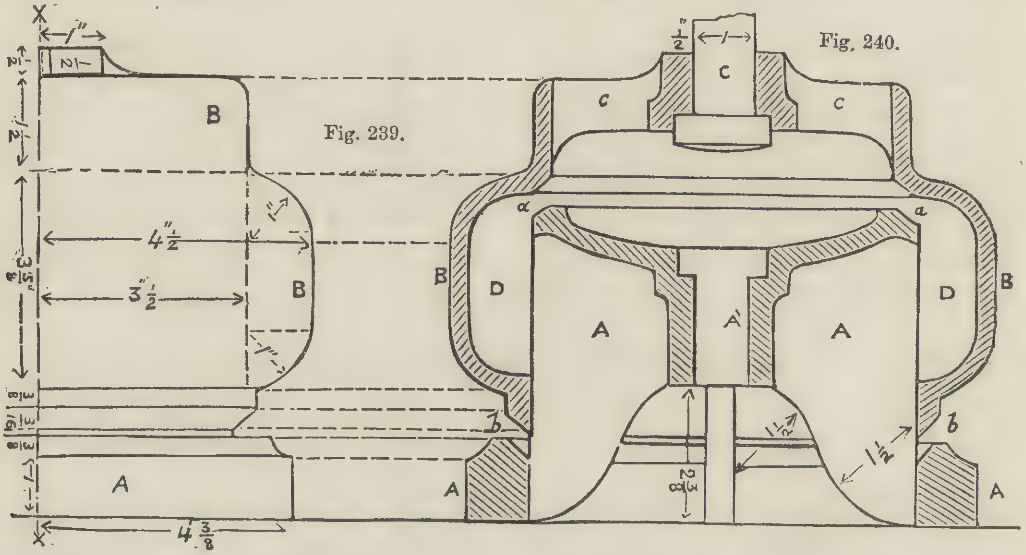


Fig. 239.

Fig. 240.

The rod or spindle, C, of the valve, B, is fixed to a centre-eye cast in one with the valve-piece, and connected to it by four arms, two of which are shown at *c c*. Of the other two, which are at right angles to these, one is hidden by the rod C, and the other has been cut off by the plane of section.

The seat is similarly formed with four arms, or deep feathers having an angular ring at the base, the top edge of which is bevelled and ground to fit the lower edge of the valve B, and when lifted, forms the opening shown at *b*.

The student will do well to draw the whole of the elevation (Fig. 239), of which only half is given in the plate; but as the object is perfectly symmetrical, there will be but little difficulty in doing this.

Having drawn the centre line, X X, set off on each side 4⅜″ for the width of the fixed seat, A, erect perpendiculars, and make the seat 1″ high.

The chamfered edge of the fixed seat is ⅜ high. It will be seen that no measurement is given for the space above it, because this is variable, being the aperture shown at *b*, which would be increased if the valve-chamber, B, were raised further, or would be closed altogether when B descends; the depth, however, of the bevelled edge of B is $\frac{3}{16}$.

Next follows a vertical rim, and ⅜ from this the widest part of the valve-chamber starts by means of a portion of a quadrant of 1″ radius, the width of the chamber being 3½″ in the upper part, and 4½″ in the middle, the height of the wider portion being 3⅝″, and of the narrow, B, 1½″, the arms rising to a central boss ½ inch higher.

Fig. 242.—The plan of this object is very readily obtained, for it will be clear that A C rests on a circle, and that B′ D′ being the diameter of a circle equal and parallel to A C, and seen under precisely similar circumstances, will be represented in plan by the circle D″ B″. The diameters F G and H I being connected by the lines F H and G I, the plan will be completed.

It is, however, necessary to add the plan of the section at J K.

Now it is evident that this section is really a *circle* of precisely the same diameter as the other two, therefore a perpendicular drawn from E will cut G I and F H in L M, which will be the diameter.

But the section is not horizontal, and therefore its plan is not a circle, but an *ellipse*, of which the short diameter is the line N O, obtained by drawing perpendiculars from J and K.

To find additional points in the ellipse, divide one of the circles into any number of equal parts, as P, *p*, Q, *q*, and carry up perpendiculars to cut the elevation in the points lettered P′ *p*′, Q′ *q*. From O′ describe arcs through these points, cutting the section-line J K in P″, Q″.

From these points draw perpendiculars, and from P, *p*, Q, *q* in the circle draw horizontals intersecting them in P‴, Q‴, *p*‴, *q*‴. The one half of the ellipse is to be traced through the points, and the other half is to be obtained in a precisely similar manner.

To find the curves caused by a cylinder penetrating a sphere, the centre of the sphere not being situated in the axis of the cylinder.

Let A B (Fig. 243) be the plan, and A′ B′ (Fig. 244) the elevation of the cylinder; and let C D be the plan, and C′ D′ the elevation of the sphere.

Draw the tangent E F, which will be the plan of the vertical circle which would touch the cylinder; in other words, if a knife were passed through the sphere close to the cylinder, it would leave a section which would be the circle E′ F′, which may be projected from the section-line E F in the plan.

Now this plane, as seen in the plan, touches the cylinder at the point G, and a perpendicular raised from this point will cut the circle E′ F′ in G′, *g*.

Again, it will be clear that all the sections of the sphere parallel to E F will be circles. Therefore draw H I, which will be the plan of a circle passing through both cylinder and sphere.

From H (Fig. 243) draw a perpendicular cutting the diameter of the sphere in the elevation in H′, then with radius O H′ describe the required circle.

The plan H I of this circle shows that it is cut through by the cylinder in J and K.

Therefore, from J and K draw perpendiculars cutting the circle O H′ in J′ and K, and also in two points immediately above them, *j* and *k*. Pursuing the same method, the diameter of the cylinder produced will give the plan L M of the circle L′ M′, which the perpendiculars forming the elevation of the cylinder cut in N, *n*, P, *p*.

Similar points may be found for the back curve. It will be sufficient to show one. The line Q R represents the plan of the circular plane which would touch the cylinder on the opposite side, and parallel to E F.

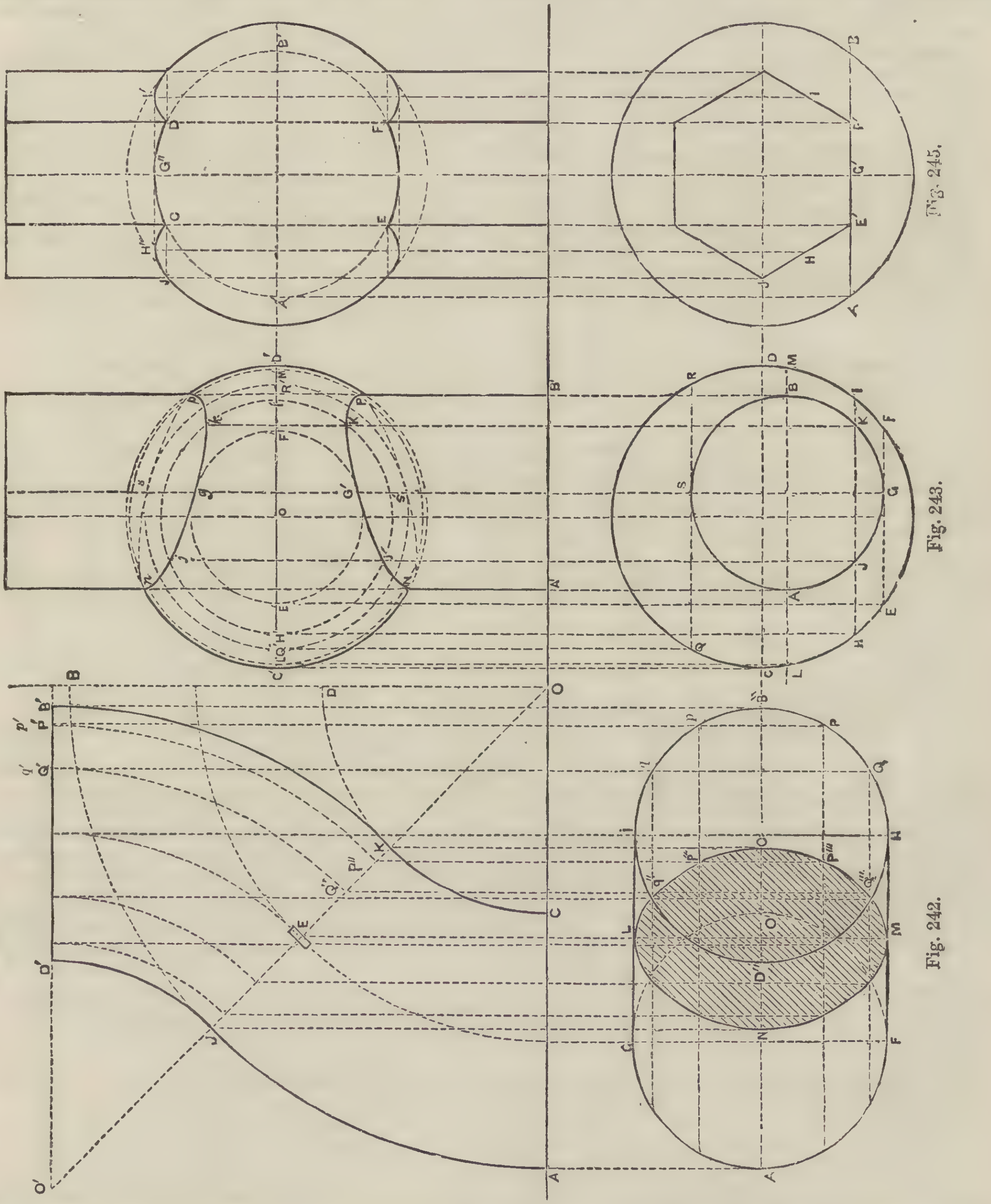


Fig. 246. Fig. 245. Fig. 244. Fig. 243. Fig. 241. Fig. 242.

This being projected, gives in the elevation the circle Q′ R′, which is cut by the perpendicular drawn from S, in the points s′ and s.

The upper and lower curves of penetration are then to be drawn through the points thus obtained.

Fig. 245 is the plan and Fig. 246 is the *elevation of a sphere penetrated by a hexagonal prism.* Draw the complete plan, and project the elevation of the prism and the external form of the sphere from it.

The last study will have rendered it clear that the plane of which A B is the plan, will in its elevation be the circle A′ B′, and therefore the curve of penetration on all the sides of the prism will be portions of a similar circle.

Thus the extremities of the arcs C D and E F are the points where the perpendiculars from E′ F′ cut the circle.

The curves on the sides of the hexagon are projected in the following manner:—

Draw perpendiculars from the middle points, H and I, of the sides, and intersect these by a horizontal from G″, the highest point in the arc; then the curve is to be traced through C H′ J. The corresponding curves will be obtained in a similar manner.

COLOUR.—VII.

By Professor CHURCH, Royal Agricultural College, Cirencester.

THE CULTIVATION OF THE SENSE OF COLOUR—TRIPLE COMBINATIONS OF COLOUR—DISTRIBUTION, BALANCE, AND QUALITY OF COLOUR.

HAVING described with some fulness of detail the relations of colours amongst themselves and to white, black, and grey, we may now extend and apply the knowledge gained to some of its practical uses of a decorative kind. Directly we begin to study combinations of three or more colours, and the important subjects of the harmony, contrast, and balance of colours, we find our ground less sure, for not only do many subjective influences come in to modify the objective realities of complex colour-combinations, but the element of *taste*—to some extent a personal element peculiar to the individual—introduces fresh difficulties in reaching a right judgment. Yet it must not be forgotten that taste in great measure depends upon knowledge, association, and culture, and may be developed from very small rudiments by proper study. Never was there a time when the opportunities for such study, in relation to taste in colour, were more abundant. Commencing with the acquirement of the knowledge of the theory and the laws of light and colour, we may proceed to study and to analyse the most pleasing and attractive colour-combinations to be found in the works of Nature and of art. Here it is that our parks and gardens, our museums of specimens of natural history and ornamental art, as well as such art libraries as that at South Kensington, become of such special use. The dwellers in a great city, if shut out from the pure blue of the sky, and the foaming white of the ocean, if debarred from the wide beauties of the open landscape, yet have an opportunity of studying the wonderful colours of Nature. Such are shown in the softened tones, and tender hues, and metallic lustres of flowers, birds, shells, and minerals, in the pictures which represent outward facts as interpreted by the intelligence and skill of man, and in the thousand and one forms of decorative art which so often express, in various degrees, the development, historical and national, of the appreciation of colour.

We may suitably commence to apply the laws of colour by a reference to the effect of certain triple combinations of primary and other colours. Some details of this kind have been already furnished when we were describing the value of black and white in separating related colours. Orange and red do not accord well together, for they are closely related by the possession of many qualities in common, being bright, warm, and exciting to the eye, and so similar as to have their boundaries confused when placed together. A white line placed between a red and an orange space or device of colour not only serves to separate them, but to deepen and enrich their tone, by virtue of the law of contrast. But it does not do this so effectually as a line of black, which, affording very nearly the strongest possible contrast with orange and a powerful contrast with red, brightens both of these colours considerably, without actually causing the whole combination to reflect more light to the eye, but rather less. Now if we wish to separate two related colours from each other by the use of white or black, and these colours should happen to be, like blue and violet, of a cool retiring quality, and less exciting than orange and red, black will prove itself much inferior to white. Deep tones of blue and violet are so closely related to black that the latter effects little towards their separation, while it is itself injured by contact with them, acquiring a rusty hue. But white, on the other hand, while it deepens these colours, renders them purer, and by itself acquiring a faint tinge of the complementary yellow or orange (in obedience to the law of simultaneous contrast) causes their differences to appear more distinctly. Still there is a triple combination slightly preferable to that of blue, white, and violet; it is formed by the substitution of grey for white. The contrast becomes less violent, and is undoubtedly more agreeable. Without going through the whole series of primary and secondary colours in their relations to one another, and to grey, white, and black, it will be useful to furnish an outline of the principles by which such combinations may be classified and valued. Triple assortments of this kind may be arranged in three groups:—

1. Two primary colours, with (*a*) white, (*b*) grey, (*c*) black.
2. One primary and one secondary colour, with white, grey, or black.
3. Two secondary colours with white, grey, or black.

1. Of the first species of triple assortments there may be nine varieties, even if we limit the list to those varieties in which the colours are separated by the white, grey or black:—

Yellow—with white, grey, or black—and red (three varieties).
Red—with white, grey, or black—and blue (ditto).
Blue—with white, grey, or black—and yellow (ditto).

2. Of the second species of triple assortments there may be twenty-seven varieties:—

Yellow—with white, grey, or black—and orange (three varieties).
Yellow—with white, grey, or black—and violet (ditto).
Yellow—with white, grey, or black—and green (ditto).
Red—with white, grey, or black—and orange (ditto).
Red—with white, grey, or black—and violet (ditto).
Red—with white, grey, or black—and green (ditto).
Blue—with white, grey, or black—and orange (ditto).
Blue—with white, grey, or black—and violet (ditto).
Blue—with white, grey, or black—and green (ditto).

3. Of the third species of triple assortments there may be nine varieties:—

Orange—with white, grey, or black—and violet (three varieties).
Violet—with white, grey, or black—and green (ditto).
Green—with white, grey, or black—and orange (ditto).

In these lists we have presented the simplest kinds of triple assortments in their baldest forms. Before we can form any just idea of their relative merit, so far as the degree of pleasure they convey to the eye is concerned, it will be necessary to look a little more closely at the various conditions under which these assortments of colours may be made or met with. Supposing our colours to be produced by the purest pigments, and each one of them to present its characteristic depth of tone (which we have previously described as its *equivalent*), we shall yet find that the effect of any one of our series, above given, of simple triple colour-assortments depends upon many minute particulars. Amongst these we may name, as the most important, the relations of the colour-elements of each assortment, so far as concerns their—

1. Distribution, as to form and surface.
2. Proportion or balance.
3. Quality, as to warmth, brilliancy, etc.

The consideration of the texture of the coloured material, its lustre, transparency, and similar physical character, together with the modifications of colour produced by different kinds of illumination, being deferred for the present, we proceed now to say a few words as to the distribution of the constituents in combinations of three colours. The simplest case is the presence of the three elements on three equal and similar spaces, such as a square space of yellow separated by a similar square space of white from one of red; or we may have a disc of red, surrounded by a ring of white, and that bordered by a second ring of yellow, each surface being of equal area. Differences of area, as well as of form, may also be taken into consideration. The white space may be reduced to a narrow band separating the yellow and red, or it may be increased so as to form

several strips, and then arranged in the order white yellow, white red, and so on. This is not only an alteration in the relative space occupied by one of the elements in a triple assortment, but it involves an alteration in the way in which the element is distributed. The mode of distributing colours, however, belongs rather to the subjects treated of in the "Principles of Design," although it undoubtedly influences to a great extent the quality of the colour-effects produced in any assortment of hues. We will, however, say a few more words about the effects of the mode of distributing colour on a surface when we have touched upon the two allied subjects of the balance of colour and the quality of colour.

The balance of colour has been already alluded to in Lesson IV., and has likewise been explained by the writer of the "Principles of Design."* The principle which underlies the idea of the balance or proportion of colour is that the eye and mind demand for their satisfaction the presence of the several elements of the chromatic scale in some form or other of combination, and in such proportions as shall be competent to re-constitute white light, whiteness, or greyness. But there are three facts which must not be lost sight of in studying the balance of colour in any actual composition. The first of these facts is that our purest pigments are far from representing the several colours of the spectrum, and so we can only approximate our groups of coloured surfaces very roughly to the proportions required by theory. The next fact is that this theory itself is merely a provisional one. For, as we have already pointed out (see "Colour," No. IV., page 211), Professor Maxwell and other observers have shown that the commonly received theory as to the primary colours is not altogether true or competent to explain some of the most important phenomena of colour. Convenient this ordinary theory certainly is, while its defects do not obtrude themselves upon our notice when we examine the impressions produced by coloured terrestrial objects. But we will not go over this ground again here, merely mentioning the inherent defectiveness of the usual theory of the coloured constituents of white light, in order to point out how it is that we feel unable to claim any real or complete scientific basis for our present views as to the balance of colour in a composition. We must, however, for the present accept and utilise these views in default of better; but it would be improper to claim for them an unhesitating acceptance or adoption. But even supposing the theory of the balance of colour to have greater pretensions to truth than it really possesses, there is a third fact which tends to lessen still further its value and applicability—we refer to the satisfactory and agreeable nature of many colour-combinations which glaringly transgress its demands. Yet the fact that the contemplation of a single pure and bright colour viewed alone gives us pleasure no more negatives the idea of the greater and more complex kind of pleasure derived from an assortment of colours than the sweet quality of a particular note in the human voice or a musical instrument disproves the superior beauty of a chord. So, too, just as some airs have but a very limited range of musical tones, yet possess a simple and quiet beauty of their own, so a few colour-tones of the same scale, or a series of three or four closely-related colours, may give us great pleasure, and seem to employ and satisfy the eye. There can be no doubt, then, that while the colour-elements are beautiful by themselves and in a large number of simple combinations, fresh beauties of other and less obvious sorts are brought out by assorting colours in obedience to certain principles. So far as balance or proportion is concerned, we may say that of the most brilliant and luminous colours, such as yellow, we need least in any assortment; of colours of intermediate power, such as red, a larger quantity may be used; while the deep and more retiring blue demands a space at least equal to that occupied by both the yellow and the red. White will be used most sparingly, as being more brilliant than yellow; and black will likewise be employed temperately, as the deepest of all tones, and giving the most violent contrasts possible. Here it is that the immense value of grey and the tertiary hues is especially felt. For suppose we desire to convey some particular impression by a colour-assortment, we can often do so, without widely departing from the balance of colour, by introducing grey into the assortment, either by itself or mixed with a colour, so as to produce a "broken tone." Thus, if we desire a quiet but not cold assortment of colours, we may mix with our yellow enough grey to turn it into citrine, and then the complementary violet, which in a binary assortment is the other necessary constituent, will not produce so striking a contrast as with the original yellow. We may, also, then increase the proportion of surface covered by the citrine, so as to lighten the whole effect. In such a combination, white, too, may be introduced with more satisfactory effect, as it accords better with yellow when the latter has been made less brilliant by admixture with grey than it does with pure yellow, which too much resembles it in brilliancy. In considering the balance or proportion of this or any such arrangement, or of those arrangements in which there is a manifest deficiency of some one colour-element, it should not be forgotten that we have continually occasion to devise combinations of colour which are *not intended to stand alone;* indeed, it is usually impossible, even if it were desirable, to isolate the colour-assortments of natural or artificial origin. Thus the very elements which may be needed to supply the chromatic balance in, say, an old blue and white jar of the porcelain of Nankin may be furnished by the deep brown stand on which it is placed, or by the furniture or paper of the room. We must not, then, expect in all the fixed or movable decorations of a house that perfectly balanced proportion which the whole of them taken together may offer. The position, use, and material of each coloured object will necessitate a particular preponderance of certain colours, while a perfect colour-balance in each part would constantly lead to a very imperfect one in the whole system or arrangement.

Something has already been said of the quality of colours, as influencing our estimation of the value of their several assortments. We here return for a short space to this subject. In describing the primary and secondary, we have shown that their fullest and purest tones differ greatly in different cases. No tone of yellow can be obtained of equal depth with the corresponding tone of blue. The brightness or brilliancy of the yellow will always cause it to contrast, not only so far as the tone is concerned, but also in relation to colour, with the blue. To deepen the yellow we must mix black with it, turning it into brown. Colours such as green and red may be obtained of full tones and yet equal intensities, so as to offer no contrast of tone, only one of colour. The inherent brightness or sombreness of colours forms, then, one of their most important qualities when they are introduced into combinations or assortments. Of course, the quality of colours is variously modified by admixture with other colours, or with white, grey, or black. Combinations of secondary and tertiary colours and hues, while influenced by the same principles of distribution and balance as those just laid down, are less capable of yielding discordant and unsatisfactory assortments. The contrasts between them are less violent, while their assortments admit of more varied treatment and more subtle expression. We shall have occasion to notice the great value of several of the more indefinite and mixed hues in the remaining papers of this series.

* TECHNICAL EDUCATOR, Vol. I., p. 221.

BUILDING CONSTRUCTION.—XIII.

JOINTS IN TIMBER (*continued*).

In the present lesson we continue the instructions commenced in our last for joining pieces of timber together. The importance of ascertaining the best methods by which separate pieces of timber may be joined together so as to present the greatest amount of resistance to pressure, whether vertical or lateral, cannot be insisted on too much, for it is clear that considerable injury might result from the adoption of a defective mode of making a joint. It is in cases of this kind that technical education becomes so strikingly apparent. Of two kinds of joints, one of which presents certain mechanical advantages, an unskilled or rather untaught workman will select that joint which happens to suit his fancy, while the skilled workman will at once adopt that which he can see will be most effective from a mechanical point of view.

Fig. 105 shows a mode of lengthening timber, first by means of *halving*, and additionally by a *dovetail*. This joint is supposed to be supported from below, as in the case of a wall-plate, etc. The dovetail gives this joint power to resist any tension which

might tend to pull the parts asunder, and also strengthens it against lateral pressure.

Figs. 106 and 107 are two forms of scarfing which are very generally used. The principles of scarfing having been fully explained, it is not necessary to repeat them here. Fig. 107 shows the "sally," or point given to the end of each part to resist lateral pressure.

the sally at the end must be formed by a very obtuse angle, and the edge of the points, and of the parts which receive them, must be worked very true, or there will be a chance of the wood being split by vertical pressure.

Figs. 109 and 110 are joints used for lengthening timber when supported by columns or walls.

We now proceed to speak of joints properly so called.

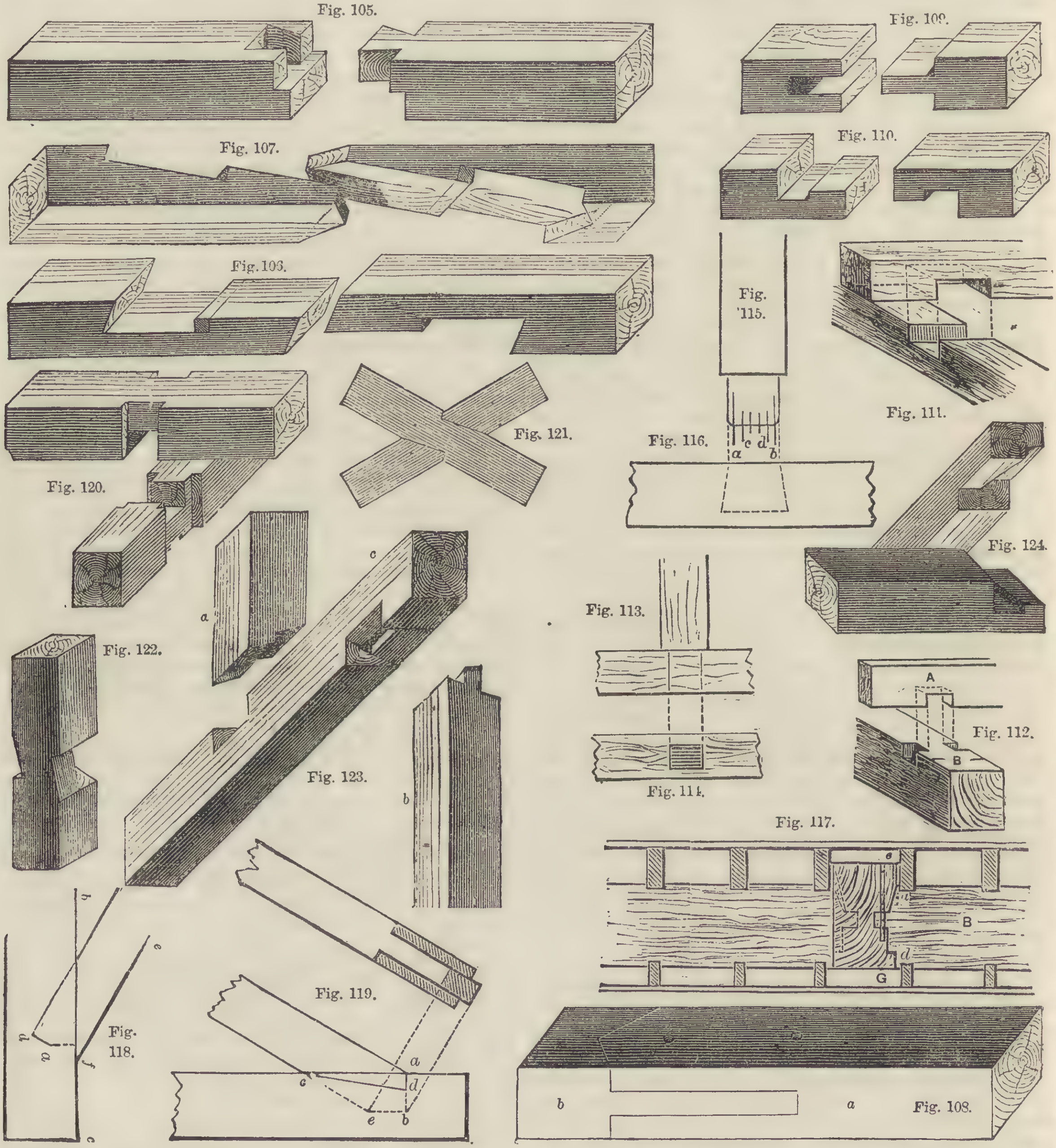


Fig. 105. Fig. 109. Fig. 107. Fig. 110. Fig. 106. Fig. 115. Fig. 111. Fig. 121. Fig. 116. Fig. 120. Fig. 124. Fig. 113. Fig. 122. Fig. 112. Fig. 123. Fig. 114. Fig. 117. Fig. 119. Fig. 118. Fig. 108.

Fig. 108 is a joint effected by a tongue or tenon in the one part (b) fitting into a mortise or slit of similar width in the other (a). This is considered a very good joint when the beam so joined is supported by a column underneath the joint. In such cases it may be placed on its narrow side, so that the width of the tongue may be vertical. The sides of the part a then strengthen the beam against lateral strain. This method, too, is found very effective when used vertically, there being no possibility of the parts slipping over each other. In this case

Where two pieces of timber of equal thickness cross each other, and the joint is to be *flush*—viz., the pieces when joined are to form a flat surface—they are *halved* together; that is, a piece is taken out of each of half its thickness and of the breadth of the piece which is to cross it, and thus the one drops into the other, as shown in Fig. 111, and pins are then driven through both.

When a joist is to rest on a girder, the joint is said to be "notched in" (Fig. 112), pieces of an oblong form being taken

out of the opposite upper edges of the girder or lower joist, and a piece (A) is taken out of the lower edge of the upper timber equal to the piece (B) left standing in the middle of the girder. The upper one then drops into the notches.

When the beams stand square with each other, and the strains are also square with the beams, and in the plane of the frame, the common mortise and tenon is the most common junction. This is shown in Figs. 113 and 114, and will not require any explanation. A pin is usually put through the joint in order to counteract any force which may tend to separate the pieces. Every carpenter knows how to bore the hole for this pin, that it shall have the tendency to draw the tenon tightly into the mortise, thus causing the shoulder to butt closely without the risk of tearing out the piece of the tenon beyond the pin if he draws it too much. Square holes and pins are by far preferable to round ones for this purpose, bringing more wood into action with less tendency to split it. A joint of this kind often used is that called "foxtail joint," the peculiarity of which is that the mortise (Fig. 116) is not cut *through* the wood, and still the tenon is firmly wedged in. The mortise is cut wider at the bottom than at the top; the end of the tenon (Fig. 115) is then slightly split in several places, and wedges of hard wood are inserted; the tenon is placed in the mortise, and the piece driven in with the mallet. As the broad ends of the wedges are forced against the bottom of the mortise they split the end of the tenon, which thus spreading out fills up the wider part of the cavity. In order to prevent the wedges splitting the piece beyond the shoulder, the outer wedges placed near the edge of the tenon should be very thin, and project further than the others; the succeeding pairs should be rather thicker as they follow inward, and should stand out from the end less and less. Now it will be clear that *a* and *b* will touch the bottom first, and as they come into action will split off a very thin slice, which will bend without breaking; the wedges *c* and *d* will act next, and will have a similar effect; thus, the rest, as they come into operation, will be prevented splitting the tenon further than is required. The thickness of all the wedges added together should be equal to the difference between the width of the mortise at the top and at the bottom.

The binding joists of a floor are mortised into the girder. In this case the tenon should be as near the upper side as possible, because the girder would, in the event of its yielding to any strain, become concave on that side; but as this exposes the tenon of the binding joist to the risk of being torn off, it is necessary to mortise lower down. The form of mortise (illustrated in Fig. 117) usually given to this joint is extremely judicious. The sloping part, *a*, gives a very firm support to the additional bearing, *a d*, without much weakening the girder. This form should be adopted in every case where the strain has a similar direction; *e* is a pin driven in from the top of the girder through the tenon, which gives it additional security.

The joint that most of all demands careful attention is that which connects the ends of beams, when one pushes the other very obliquely, putting it into a state of tension. The most familiar instance of this is the foot of a rafter pressing on the tie-beam.* When the direction is very oblique (in which case the extending strain is the greatest), it is difficult to give the foot of the rafter such a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project a small distance beyond the foot of the rafter; but, indeed, the dimensions which are given to tie-beams for other reasons are always sufficient to give enough abutment when judiciously employed. This joint is, unfortunately, much subject to failure by the effects of the weather. It is much exposed, and frequently perishes by rot or by becoming so soft and pliable that a very small force is sufficient either for tearing the filaments of the tie-beam or for crushing them altogether.

Long tenons to the ends of rafters are not now so much used as they formerly were. They have been observed to tear up the wood above them, and thus to push their way to the ends of the rafters. Carpenters, therefore, now give to the toe of the tenon a shape which abuts firmly in the direction of the thrust on the solid bottom of the mortise, which is well supported on the under side by the wall-plate. This form, which is represented in Fig. 118, has the further advantage of having no tendency to tear up the mortise. The tenon has a small portion (*a*) of its end cut perpendicular to the surface (*b c*) of the tie-beam, and the rest (*d*) is perpendicular to the length (*e f*) of the rafter.

Fig. 119 is another form of tenon for the foot of rafters. Here the whole thickness of the rafter is brought into service, and the end *a b*, cut so as to make a right angle with the surface of the tie-beam, is sunk into it, the line *c* gradually slanting down to *d*; the tenon *c d b e*, then, whilst it is the whole length of the part of the rafter entering the tie-beam, is only a part of its thickness; and, as will be seen in the illustration, the end of the rafter and tenon, *a b*, forms a perpendicular with the upper surface of the tie-beam, whilst *b e* is at right angles to *b a*.

This joint is common on the Continent, but has been objected to by some carpenters on the ground that, should there be any shrinking in the king-post which should allow it to sink, the rafter would turn on the point *c*, as on a pivot, and the point *b*, describing an arc, might push up the wood above it; but this does not seem very likely. It is quite impossible, within the limits of the present lesson, to dwell longer on this department of woodwork; but enough has been said to give important aid to the student of that branch of Building Construction. The joints by which the ends of rafters abut on the beams are often bound by iron straps. These will be shown in the illustrations connected with roofs.

Fig. 120 shows a joint of a similar character to Fig. 111, but more complex in its working. It is not adapted for large works, being still more weakened by the cutting away of the pieces at the side.

Of course, the joint is only half as strong as the timbers originally were, owing to half the thickness of each being taken out. If, therefore, they are of any considerable length, the joint must be supported.

Fig. 121 shows the method of halving when the timbers cross each other at any angle, and Fig. 122 is a separate view of one of the parts.

Fig. 123 exhibits two methods (*a* and *b*) in which timbers can be united at right angles to each other when they are not to cross. These illustrations are too plain to need any explanation.

Fig. 124 is one of the numerous methods for uniting timbers at an angle of a building by means of a dovetail joint, by which means the end of each is locked into the end of the other.

* The parts to which these names apply will be found in a future lesson.

TECHNICAL EDUCATION ON THE CONTINENT.—XIII.

THE NETHERLANDS—CONCLUSION.

BY E. A. DAVIDSON.

As a preliminary to all we have to say in relation to the education of the Netherlands, it is well to state that the Dutch law provides that there shall be at least one technical school to every 10,000 of the total population, for instruction in drawing, modelling, etc., in addition to the other branches of general education.

These schools consist of (1) day and evening classes, in which workmen, their children, and apprentices receive instruction in mathematics, mechanics, chemistry, and natural philosophy; together with such sciences as bear immediately on the industry of the district; geography, history, drawing—sound and practical in its character; modelling in clay, carving in wood; and in some, English, French, or German. (2.) Higher schools, for the education of masters, managers, and the trading classes generally. In these, the course of instruction embraces the higher branches of science, whilst the Royal Polytechnic Institution, at Delft, is an industrial university which may stand a very fair comparison with those of Hanover and Darmstadt, giving as it does an education in theoretic and applied science to such an extent, that it supplies the best trained engineers, naval and civil architects, and other professional men to the country.

The state of middle class and technical education in the Netherlands was well illustrated in the International Exhibition held in Amsterdam in 1869, where a good collection of drawings, busts, models, etc., was displayed by a large number of schools, and was singularly complete and satisfactory.

This collection was well arranged by itself, and formed one of the most striking features of the exhibition. The three Government inspectors of this class of instruction in Holland had invited all the schools under their control to exhibit, and upwards of forty had responded to the invitation. Of these, four were day and evening schools, sixteen were evening schools only, four schools of art, and sixteen were drawing schools, besides various trades and industrial schools in Amsterdam.

The works were divided into four classes:—

(*a.*) Drawings from Nature.

(*b.*) Drawings from copies.

(*c.*) Rectilinear, architectural, and technical drawings from copies and models.

(*d.*) Designs for buildings made by the pupils themselves.

The number of drawings sent up for exhibition was so great that the inspectors were compelled to exhibit selections only, the remainder being left in portfolios and boxes piled under the tables; yet a complete day spent in looking through these was so much time very profitably spent to any one interested in the subject of drawing taught on a sound system. It must be remembered that we are not here speaking of drawing in connection with fine art, we are not treating of the education of artists, but of workmen; and therefore the question of value is, how far the studies apply to the different walks of industry, how far they fall short of, or, what is worse, shoot beyond the proper standard.

There is no doubt that in some of the Continental schools manipulation is carried much beyond the required point. The object, after all, is not so much to make a nation of painters as to train up a body of skilled artisans, capable of building the best houses, doing the best carpentry, iron-work, etc., and blending the best colours in painting, in carpets, in prints, or in wall papers; therefore, clearness and boldness in delineation, correctness in form and depth of shadows, correct contrasts, and tasteful blending of colours, are the points to be looked to as of infinitely more importance than any amount of finish; whilst in design, no form, however beautiful in itself, is of the slightest value if not adapted to the purpose for which it is intended or to the material in which it is to be manufactured.

One of the earliest schools for technical instruction in the Netherlands is that of the *Society Mathesis Scientiarum Genetrix*, of Leyden.

This society was established as early as 1785, by the Brothers Van Campen, Pieter Ryk, and Bartholomeus Van der Broeck—all architects, land measurers, and otherwise practical men—and to these belongs the honour of having first detected the necessity for scientific instruction for the working classes in their country. From the path of utility traced for this institution by its founders, successive governors and patrons have never swerved, but have constantly introduced every novel educational appliance, such as the Dupuis or Pestalozzian methods, etc.: this school has persevered for eighty-three years in its endeavours to create good citizens and skilful artisans, and at this honoured work it continues to labour with great success. One of the most important organisations for this object is the "Society for Promoting the Interests of the Working Classes at Amsterdam" (*Maatchappi voor den Werkenden Stand*), which was established in 1854, and which is now working with the greatest success, its patron being the Prince of Orange.

This society promotes in every way the interests of its contributors: (1) by giving scientific and practical education to the young; (2) by assisting as far as possible in the social, moral, and intellectual development of the working classes.

The number of contributors is at present 650, at a yearly subscription of 8s. 4d.—not quite 2d. per week.

The objects of the society are attained in various ways:—1. The Scavenger's Brigade. On very moderate terms the public roads and thoroughfares are swept and cleaned, thus procuring employment for many persons, and improving the sanitary condition of the town. 2. The Benevolent Fund, affording relief to workmen temporarily disabled, by accidents happening to them in the exercise of their trade. Only workmen employed by contributors have any real right to this relief; in many cases, however, the fund has also assisted the widows and orphans of other workmen killed by accidents. 3. Procuring employment for needlewomen. This division acts by giving instruction in the use of sewing-machines, and providing such for indigent women who repay the fund by weekly instalments. 4. Lectures for the working classes, established in 1866. During the winter of 1870 fourteen popular lectures were delivered to persons of both sexes, the number of visitors varying from 600 to 1,000. The subjects had reference to physics, political and social economy, moral philosophy, the art of teaching, history, literature, music, and the arts. Besides the above, four lectures were given on natural philosophy expressly for workmen, which were attended by 400 of the class for which they were intended. 5. The society has also organised exhibitions of the works of artisans, has awarded medals to such as had distinguished themselves in other exhibitions, defrayed the expense of a visit of a body of working men to the Paris Exhibition in 1867, and by rewarding such as by honesty, industry, and fidelity remain for a lengthened period in the same employ. 6. The school for workmen's sons, which is the most interesting—we may say the most important—of the various agencies; and as some of the results attained were exhibited in 1870 at the Working Men's Exhibition in the Agricultural Hall, London—where, no doubt, they were seen by many of our readers—an account of these schools will be well received. The schools were established in the year 1861, and receive a subsidy from the city of Amsterdam.

In the year 1866, King William III. presented the school with a large and important collection of models, implements, and tools. New buildings were erected in the following year at the Weteringschams, on which occasion there was a great manifestation of public sympathy in favour of the school, Prince Frederick and the Government of the province taking part in the proceedings. There are 125 pupils, of ages varying from thirteen to sixteen years, the sons of working men, and there are thirteen teachers; those in the practical works being actual artisans, who, having studied the scientific branches, become as it were "professor carpenters," "professor smiths, etc." The course of studies comprehends free-hand, linear, mechanical, architectural, and model drawing, together with bold and broad shading from objects, and practical design; but the system of drawing embraces more than this, for, besides the drawings exhibited on the walls of the building, there was a portfolio of drawings which it is not too much to say, speaking educationally, was worth its weight in gold. There were large architectural plans, elevations, sections, and working drawings, projections of every kind, relating to the work of the carpenter, builder, engineer, etc. To look through these alone was a lesson in the class of drawing necessary for the artisan. Here were wheels single and in gear, screws of every kind, developments of surfaces, forms of penetrations, such as one could see must have been worked out by pupils who understood what they were about—they could not have been copied.

Then they learn physics, algebra, mathematics, mechanics, building and mechanical construction, carpentry, forging, turning, embossing, carving, etc., being kept to study from eight a.m. to eight p.m., with an interval at noon; but it must not be supposed that the whole twelve hours are spent in actual study. Everybody who has seen any of these boy workshops must have noticed the intense delight the young artisans take in the work. As a rule, all boys are fond of manual work of some sort, from cutting out boats with their knives from pieces of firewood, to making models of steam-engines; it is, therefore, only utilising their powers, and turning them into a direction which may assist them in their future career. The whole system was brought before the public in such a tangible form, and was so ably explained and so courteously exhibited by the representatives of the Royal Commission, that the memory of the admirable collection and the instruction to be derived therefrom will long remain with those persons who are interested in technical education. Amongst the actual work exhibited by the pupils in these schools were numerous pieces of carpentry and joinery, a portion of a staircase of the real size, joints in timber as used by both carpenters and joiners, methods of trussing beams, sash-frames, panelling, mitreing and dovetailing a bookcase with carved open-work, a model of a timber roof, with its trusses, purlins, rafters, etc.—not only complete, but absolutely correct in every particular—part of a spiral banister rail (and every joiner who reads these lines will appreciate the difficulties of these), exquisitely formed and joined. There were some good turnings in wood, architectural modelling in clay, and several excellent timber constructions. Next came the work in iron, good as to its casting, forging, hammering and

filing, and all systematically taught, from the riveting shown in a common rough iron pail, to an admirably made ornamental iron railing; tools and implements, filing, punching, chasing, and bending, all equally well displayed. We use these words advisedly, because we do not wish to be mistaken—we are speaking of *education*, not of trade: we say, therefore, the boys are *learning* these branches, and that these exhibits are portions of their *daily work*. They are not made for show, they were not exhibited in competition with the work of experienced artisans. Yet let us ask any foreman or employer to pause and ask himself whether he would not find a youth who came to him as an apprentice more useful than the mere "gawky" school-boy, who cuts his fingers the first time he touches a tool, and who shirks work because he is afraid of dirtying his hands; and we put it to the common sense of the whole country, whether, if a boy begins his apprenticeship with first the scientific education which these little Dutchmen get, and then the manual skill, they will not be able to devote themselves to higher things, and work out their faculties which would otherwise have remained dormant, and will thus develop the powers given them by an Almighty Creator to His honour, and to the credit of their native land.

We have in these articles spoken of the technical universities, of the classes for artisans, and the schools for boys; we approach the lowest stage, yet that lowest stage must not be neglected; and as in starting we said that the most elementary education should have a tendency to practical purposes, it may amuse as well as instruct our readers—and it is as well to leave a smile on the faces of those instructed as to cause them to feel relieved that such a heavy lesson is over. We will speak then of technical instruction to *babies*, and we will go to Belgium for an illustration of such a system. Here we shall find the *Crèche École Gardienne*, an institution which has been founded for over a quarter of a century. It takes charge of every baby brought to its doors, from the ninth day after its birth to its thirteenth year, and it is divided into three departments: (1) the *Crèche*, in which babies are kept on payment of six or twelve cents. a day, according to age, or gratis if indigent, until they attain the age of thirty months; (2) the *École Gardienne*, to which they are transferred, and where they are attended to gratis, or for an additional one or two cents. a day. Here they remain until their seventh year, when they are transferred to the third and highest division, the *Section Professionelle*, either gratis or on payment of an additional two, four, or six cents. per diem, according to their age. On attaining their thirteenth year, the boys are apprenticed to trades, and the indigent girls are put into Government schools of extended primary instruction, whence they take service or are provided for as schoolmistresses.

In the medium division, from thirty months to six years of age, straw-plaiting, twisting paper, folding and cutting paper, rough drawing, and modelling are taught. In the *École Professionelle*, reading and writing, the elements of arithmetic, grammar, and European geography, with a little natural history, are taught. In the case of girls, needlework of different kinds is added; with boys, drawing, modelling, etc., are pushed to greater perfection.

The limits of our papers have been reached, and we can only mention that similar systems to those described are carried out in Bavaria, Austria, Switzerland, Sweden, Denmark, Italy, etc., and it is most satisfactory to know that in our own country technical education has taken such root that at no very distant date we shall rival and, it is possible, outstrip the Continental nations.

THE STEAM-ENGINE.—VI.

By J. M. Wigner, B.A.

THE CYLINDER (*continued*)—STUFFING-BOX—SLIDE VALVES.

When the cylinder is cold, as at starting, a portion of the steam condenses on its inner surface, and settles as water in its lower part. This, if allowed to accumulate, would very materially interfere with the working of the engine. "Blow-off cocks" are therefore introduced to carry off the condensed water, and through these some of the steam is allowed to escape. They should be opened for a little time when starting the engine, until the cylinder becomes thoroughly heated. Almost all condensation will then cease, and they should at once be closed again. If the cylinder is exposed to the air, it loses heat by radiation, and therefore the amount of condensed water is largely increased. This waste may, however, to a very great extent, be obviated by jacketing the cylinder—that is, covering it with some non-conducting substance, which prevents the radiation of the heat. Felt, or some similar material, is usually employed for this purpose, and outside this strips of wood are placed, and held in position by brass bands, which give a finished appearance to the whole.

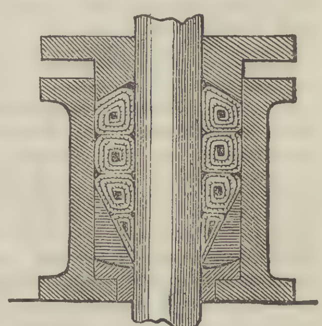


Fig. 28.

The under side of the piston is sometimes nearly or quite even; more commonly, however, it is considerably hollowed out, to allow the nuts for adjusting the packing-springs to be got at easily, or else the end of the piston-rod projects a little way where its nut is screwed on. In these cases the lower end of the cylinder is so shaped as nearly to fit it, and thus to obviate an unnecessary waste of the steam. The interior round the ports is also cut away a little, so as to allow the steam to pass below the piston when the latter is at the end of its stroke. Were it not for this, the piston would completely cover the port, and thus the engine would not act unless the fly-wheel had sufficient momentum to raise the piston a little way, and allow an entrance for the steam.

In the centre of the cylinder-cover an aperture is cut for the piston-rod to pass through, and this has to be packed, so as to allow of the rod moving up and down without excessive friction, but at the same time to prevent any leakage of the steam. This is accomplished by means of a "stuffing-box," the construction of which will be understood from Fig. 28. The aperture in the cylinder-cover is of larger diameter than the piston-rod, so as to avoid the friction of iron against iron. A cylindrical cup or box of larger diameter is then fixed to the cylinder-covering over the opening and this is filled with plaited hemp, or some similar material, well lubricated. A cover is fitted to the upper end of the stuffing-box, which can be forced down by means of a screw, so as to compress the packing to any required extent, and in this way the effect of wear is easily obviated.

This packing must be kept sufficiently charged with oil or tallow, otherwise the steam will escape; sometimes, however, the oil is volatilised by the steam to a limited extent, and is found to injure the piston and cylinder. A self-lubricating packing has therefore been introduced, which has met with a good deal of approval; in the figure the stuffing-box is shown as packed with this.

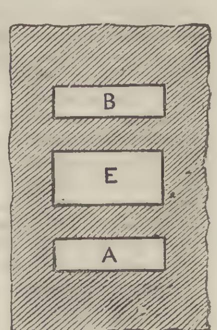


Fig. 29.

Before inquiring into the manner in which the alternate motion of the piston-rod is imparted to the machinery, we must see the way in which the supply of the steam is so regulated as alternately to enter each end of the cylinder. This may, as we have seen, be effected by means of cocks, and in the first engines made it was accomplished in this way. This plan, however, soon went out of date, and some modification of the slide-valve is now most generally adopted. In some cases spindle or "puppet" valves are employed.

The simplest form of slide-valve, and that which will best explain its action, is that known as the ordinary "three-port" slide. At one side of the cylinder is a true surface, called the "valve facing," in which there are three parallel apertures, B, E, and A (Fig. 29); of these, B and A communicate

respectively with the upper and lower ports of the cylinder, as will be seen in Fig. 30, where the same letters are employed. The centre opening, E, is the largest one, and is known as the "exhaust;" it communicates either with the condenser or the atmosphere, according as the engine is a condensing one or not. The valve, V (Fig. 30), slides over this facing, and thus allows B and A alternately to communicate with E; the other port in either case being open for the passage of steam from the boiler. Firmly secured to the valve-facing is a kind of steam-chest, C D, into which the steam-pipe, S, opens. This chest is called the valve-casing, the valve being entirely within it. In the top and bottom of it are stuffing-boxes, through which the valve-rod G passes steam-tight. This rod is firmly secured to the valve, and imparts motion to it. It is connected to some part of the engine, usually the eccentric, and is thus moved up and down so as to allow the steam to enter at the right part of the stroke, for, as will easily be seen, this is of the utmost importance. In Fig. 30 the piston is just commencing to descend, and the valve-rod is very nearly at the bottom of its stroke, so that when the piston has passed a little way down, both the ports B and A will be fully open. The steam will then pass from S by the open port B, and press on the upper surface of the piston, while the steam which filled the lower part of the cylinder during the up-stroke escapes by A into the exhaust, and thus allows the piston to descend. By the time the piston has reached the lower end, the valve-rod has been raised about twice the width of the rubbing surfaces, F F, so that now A is open to the valve-casing for the steam to enter, while the upper end of the cylinder is in communication with the exhaust by means of B and the valve.

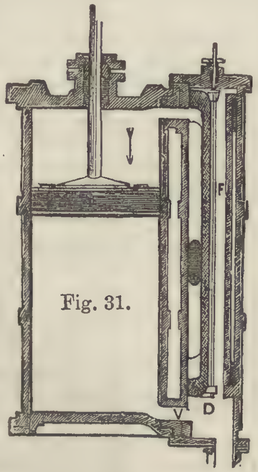


Fig. 31.

In Cornish engines the valve-rod is very frequently moved by tappets placed on it, which are caught by studs on one of the engine-rods, and thus the valves are opened and closed almost instantaneously. When, as is more commonly the case, motion is imparted by the eccentric, the movement is much more gradual. By altering the length of the faces of the valve, the steam can be cut off at any required portion of the stroke, and thus allowed to act expansively, as it is termed. We may, for example, so arrange it that when the piston is at the middle of its stroke, the further entrance of steam is stopped, while the other end of the cylinder still remains open to the exhaust.

The steam contained in the upper end of the cylinder will then possess sufficient expansive force to drive the piston completely down, though of course with less power than would be the case were the steam entering all the time. At the conclusion of the stroke the steam in the cylinder will possess only half the tension it did at the moment at which the supply was arrested; the second half of the descent, however, has been effected without any further expenditure of steam, and therefore all the power produced by it is so much additional advantage. There is evidently, then, a considerable gain by working the engine expansively, and in many cases the steam is cut off at a quarter, a sixth, or even an eighth of the stroke, the steam in these cases being used at a very high pressure. All these alterations are very easily effected by slightly modifying the valve.

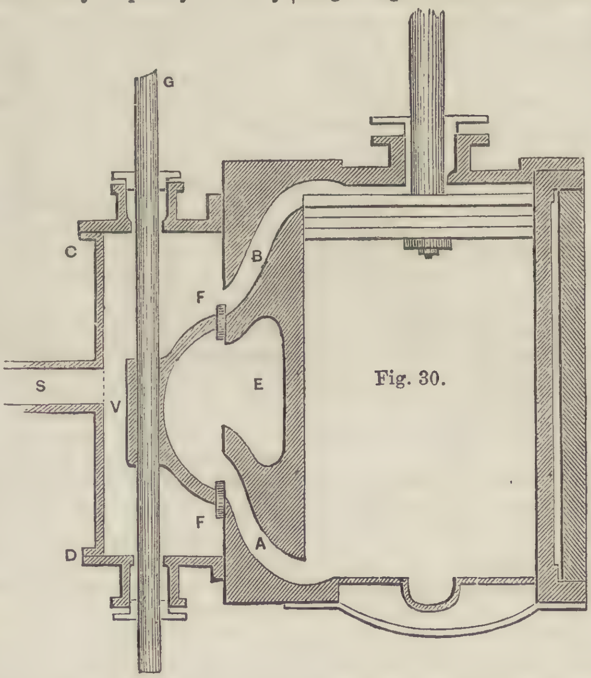


Fig. 30.

Sometimes a compound slide-valve is used which is capable of adjustment, so that the steam can be cut off at any part of the stroke we desire, and in other cases the governor-balls are made to act on this expansion gear, and in this way regulate the speed of the engine by altering the period of the stroke at which the steam is cut off, instead of by moving the throttle-valve. To explain thoroughly the construction of these valves would, however, require far more space than we can spare, and is scarcely essential to a full understanding of the engine.

The valve is usually so arranged as to give what is termed a "lead;" that is, the steam-port is opened a little before the termination of the previous stroke—thus, if the piston is ascending, the upper steam-port B is opened a little way before the up-stroke is quite completed. The steam entering this serves partly as a buffer or spring, and stops the piston more gently; it also allows the lower end to communicate more rapidly with the exhaust than is otherwise the case; and if this communication be at all impeded, the steam below the piston offers a hindrance to its motion, and thus impedes the engine.

The extension of the face of the valve by which the steam is cut off is technically known as the "lap," and it is by this that the steam is cut off at any part of the stroke. In the valve we have drawn the steam would enter, until very near the completion of the stroke.

Another form of valve frequently employed is called the "long D valve," and is shown in Fig. 31. The ports here are placed at the top and bottom of the cylinder, and the valve, which in its cross section is nearly the shape of the letter D, is long enough to cover them both. The valve is packed at both ends, so as to fit steam-tight in its chamber, and has a passage, F, passing through it from end to end. Steam is admitted through the pipes to the space between the packed ends, and the pipe seen below D is the exhaust.

When in the position here shown, the steam enters the upper end of the cylinder, and forces the piston down, while the lower end is open directly to the exhaust through the port V. When the stroke is nearly completed, the valve is depressed, and the steam now enters the lower port, while that from the upper end escapes through the passage F in the middle of the valve.

In large engines, so great is the pressure of the steam on the slide-valve, that there is at times much difficulty in starting it. To obviate this, a small engine is sometimes employed; more commonly, however, a "balanced valve" is used. In this the steam is allowed to press on each side of the valve, and thus the pressure and consequent friction are very greatly diminished.

Having now clearly understood the manner in which an alternate motion is imparted to the piston by the pressure of the steam, we may pass on to see how this motion is converted into one of rotation, or into any other kind of movement we may require. We must, however, remember that the essential part of the engine is that which we have already considered. In the cylinder and slide-valve there is a great resemblance in all engines, but in the remaining parts there is the utmost variety.

THE ELECTRIC TELEGRAPH.—VII.

ANOTHER FORM OF COMMUTATOR — THE DOUBLE-NEEDLE INSTRUMENT — ITS CODE — ORDINARY ALARUM — SELF-ACTING ALARUM.

THE single-needle instrument, described and figured in our last paper, is the form of the electric telegraph most generally employed, and may be seen at most telegraph stations. It is, however, rather complicated in its construction, and it would be a somewhat difficult task for an amateur to construct one on that model. There is, however, a much simpler form of instrument, which is now used in many places; one of these the intelligent student may easily make for himself, and in so doing he will acquire a much clearer insight into the principle and operation of the telegraph generally. He may even carry a wire to a friend's house, and thus be able to communicate with him.

In this instrument the transmitting portion of the apparatus, or commutator, is quite separate and distinct from the coil or receiving portion. The coil, with its needle, is sometimes mounted in a case similar to that of the instrument already described; but a simpler plan is to place the needle in the centre of a disc, and support this on a pillar and stand, after the manner shown in Fig. 29. The coil is then placed at the back of this disc, and covered, so as to protect it from the dust. The ends of the wire pass down the pillar, and are connected to the two binding-screws seen on the base of the instrument, which is placed in the circuit of the line-wire.

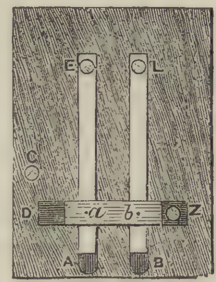


Fig. 30.

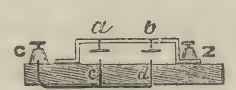


Fig. 31.

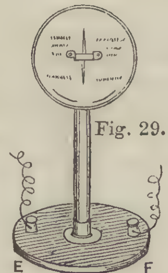


Fig. 29.

The commutator is shown in Figs. 30 and 31. A piece of mahogany or oak, about nine inches by six inches, is taken, and two strips of stout brass spring, E A and L B, are firmly fixed to it at E and L, binding-screws being fixed to each at these points. These strips are bent upwards, so that their free ends press against two studs, *a* and *b*, in the under side of a brass bridge, D Z, placed over them. The form of this will be clearly seen by the sectional view (Fig. 31).

On the extreme ends of these springs are placed finger-plates, A, B, of ivory or ebony, and by pressing on these the signals are sent. Under A and B are two stout pegs or pins of brass wire, which pass through the board, and are there connected together, and also to the binding-screw, C. The springs when at rest do not touch these pins, but remain pressing upwards against *a* and *b*.

To join up the circuit, we connect the positive and negative battery wires with C and Z respectively; E is then connected with the earth-plate, and L with one of the screws at the base of the coil—the other screw there being connected with the line-wire. Now let us, first of all, trace the course of a current which is received from the distant station. It comes along the line-wire, passes round the coil, deflecting the needle on its way, and thence to the binding-screw, L. It then travels along the strip L B to *b*, across the bridge to *a*, and along the other strip to E and the earth-plate, the circuit being thus completed through the earth-plate of the distant station.

When a message is transmitted, the current takes a different course. Suppose we desire to send an inclination to the left, we press down the left-hand spring, A, till it comes into contact with the pin, *c*. The course of the electric current will then be as follows:—From C it passes through *c* and along the strip A E to the earth-plate, returning through the coil to L, and by *b* to the binding-screw Z, which is placed on the bridge, and is connected with the zinc pole of the battery. In this way all the needles in the circuit are deflected to the left. When we desire to deflect them to the right we have only to press down B, and then, as may easily be seen, the current will pass in the reverse direction, viz., from L to E, instead of from E to L, and all the needles will accordingly move to the right.

It will thus be seen that in this instrument all we have to do is to depress the right or the left spring, according as we wish to deflect the needle to the right or to the left. This can be done rather more rapidly than the handle in the other instrument can be moved, and this commutator, therefore, has an advantage over that in point of speed. It is, however, less certain in its action, as the points of the pins are apt to become somewhat corroded or covered with dust, and the current will, of course, be interrupted by this. Both hands are commonly employed in working it, but care must be taken not to keep either spring out of contact with the stud above it while the other spring is being pressed down, as this will break the circuit.

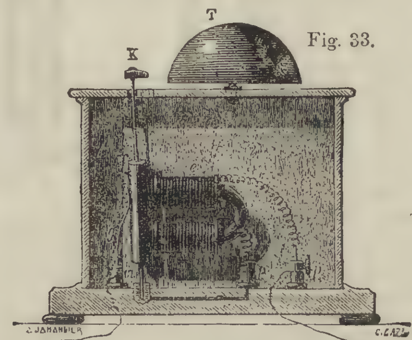


Fig. 33.

Sometimes, instead of the finger-plates, two studs or buttons are used, but the action is the same in either case.

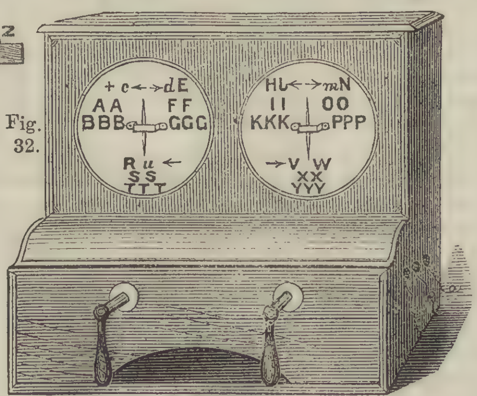


Fig. 32.

There are two main drawbacks to the use of the single-needle instrument: one is, that there is no record left of the signs, and if the eye be not very quick, or if the attention be called off, one or more of them may very easily be missed. This is, however, to a considerable extent obviated by practice. Another drawback to its use is that it is somewhat slow. To meet this difficulty the double-needle instrument (Fig. 32) was introduced, and is nearly the most rapid instrument in use. It is frequently employed on lines where there is much communication, and where speed is an important object; the great hindrance, however, to its general employment is the fact of its requiring two line-wires and two sets of batteries. It is, in fact, merely two single-needle instruments arranged side by side in the same case; each of these has a commutator and coil made on the plan already described.

The advantage of this instrument is that fewer signs are required than with a single needle.

In the latter case, only two signs can be sent with a single movement; in this, six can be so sent, since we can use either dial by itself or both simultaneously, and in either case can give an inclination either to the right or the left. No letter, therefore, requires more than three signs, and most can be sent with two. The code employed with this instrument is very simple, and is indicated by the letters on the dial-plates. Omitting Q, Z, and J, we have twenty-four letters left, reckoning + as one. The first eight of these are sent with the left-hand dial alone, the next eight with the right-hand one, and the remainder with both, used simultaneously. J is dispensed with altogether, as I takes its place; Q is represented by the needles pointing in reverse directions, the upper ends being together, thus /\; and Z is denoted by the lower ends of the

needles inclining towards each other, thus V. For the rest of the alphabet we must refer to the dials. Taking the left-hand one first, zero or + is placed once to the left of the needle, showing that this is denoted by a single beat in that direction; similarly, A is denoted by two and B by three beats in the same direction. This is shown by the number of times they occur on the disc. E, F, and G are denoted respectively by one, two, or three inclinations to the right. C is put in different type, and has an arrow pointing to it, to indicate that it requires alternate movements of the needle, first to the left, on which side it is placed, and then to the right. D likewise requires alternate beats, one to the right being followed by one to the left. The letters from H to P are represented by precisely similar movements of the right-hand needle.

The other letters, which require both needles, are marked on the lower parts of the dials. R, S, and T require one, two, and three beats respectively to the left; U is denoted by alternate beats, first to the left and then to the right; W, X, Y, and V require similar movements in reverse directions.

We may render this more clear by putting all the signs in a tabular form, thus:—

\	\\	\\\	\/	/\	/	//	///	
+	A	B	C	D	E	F	G	Left dial.
H	I	K	L	M	N	O	P	Right dial.
R	S	T	U	V	W	X	Y	Both dials.

Both hands are employed in working this instrument, and it requires more care and attention to read it; when this is attained, messages may be sent with a speed of from forty to sixty words a minute. But, as we have already stated, two line-wires and batteries are required, and these entail so much extra cost, both in construction and maintenance, that the instrument is not nearly as much used as it otherwise would be.

We have now explained the construction of two parts of our telegraph instrument, viz., the receiving and the transmitting arrangements. There is, however, another very important part to which we must refer: some means of calling the attention of the receiving clerk to the fact that a message is coming is required. He cannot be expected to keep his eye constantly on the dial-plate of the instrument, and though the click of the needle against its studs is often distinctly audible, yet this may not be noticed: an alarum is therefore an essential thing, and many different kinds have been tried.

A bell is nearly always employed for this purpose. Sometimes it is rung by the electric current itself; in other cases it is driven by clockwork, and all that the current does is to liberate a detent, and allow the clockwork to act. This is the simplest and, in many cases, the best form. A spring sets in motion a train of wheels, and thus strikes the bell. A small catch, however, engages a tooth or a stud in one of the wheels. This catch is affixed to a lever, which is so arranged that when the current passes round an electro-magnet suitably placed, the lever is moved and the mechanism set free. The alarum, therefore, continues to ring as long as the current passes and the spring is kept wound up. This kind of alarum is simple, and not likely to get out of order. Sometimes a tell-tale is affixed to it, so that, as soon as it rings, a disc is moved and indicates the fact of the bell having been rung. One great advantage of this is, that if the clerk has been away for a short time, he will on his return at once know whether his bell has rung during his absence.

Often, however, the clockwork is altogether dispensed with, the bell being rung by the electric current alone. The hammer, in this case, is mounted upon a piece of spring or wire, attached to the middle of which is a piece of iron, which serves as the keeper to an electro-magnet placed near it. This is so arranged that when the keeper is close to the magnet the hammer *almost* touches the bell; the jerk, when it is attracted, is then sufficient to strike the bell loudly without damping the sound by allowing the hammer to remain in contact with it. By this plan only one stroke of the bell is given for each current sent.

A much better plan, and one more generally adopted, is to arrange the bell so that it continues to ring as long as the current is passing. The manner in which this is accomplished will easily be learnt by reference to Fig. 33, which shows the interior of one of these self-acting alarums. The bell, T, is placed on the outside of the case, the hammer, K, being supported on a piece of spring, *m*, so that it oscillates very freely. An electro-magnet, *e*, is placed inside the case, and its keeper, *c*, is attached to the rod of the hammer. Behind *c* is a spring, *g*, in contact with it, but so arranged that when the keeper is drawn against the poles of the magnet the contact shall cease. Not unfrequently a screw tipped with platinum is substituted for this spring.

The ends of the wire which passes round the electro-magnet are connected with the screws marked *p p*; and, as will be seen, the current, after passing round the coils of the magnet, has to pass along *m* and through *g*, so as to complete the circuit. When the instrument is at rest, *c* and *g* are in contact, and, accordingly, as soon as a current is transmitted, it makes *e* into a magnet, and draws the keeper home to it, thereby striking the bell. In doing so, however, contact is broken between *c* and *g*, and the circuit being interrupted, the keeper is drawn back to its place by the spring on which it is supported. This renews the contact, and again converts *e* into a magnet, so that the keeper is again attracted, and another stroke is given to the bell. This process continues as long as the current passes, so that the distant operator, by merely keeping his key pressed down or his handle deflected, produces a continuous ringing, and thus soon draws the attention of the station to which he wants to speak.

When several stations are in the circuit, the bell at each rings; the clerk then mentions the one to whom he wants to speak, and as soon as that one acknowledges, he sends the message. The other clerks can, if necessary, short circuit their own instruments, so as to cause less obstruction to the passage of the current.

NOTABLE INVENTIONS AND INVENTORS.

X.—POTTERY AND PORCELAIN (*concluded*).

BY JOHN TIMBS.

At the time of the French Revolution, fine specimens of Sèvres porcelain in the royal palaces and mansions of the nobility were destroyed. These productions have since declined in value and in beauty; but previously a complete service for Louis XVI. was manufactured, each plate of which cost £24. In the palace of the Tuileries there is, or was, a superb vase of Sèvres porcelain, which cost £1,000. In 1800 M. Bronguiart was appointed director of the factory. "He held the appointment during forty-seven years, and originated the celebrated *Musée Céramique*, consisting of an historical series of specimens illustrative of the ceramic art in all times and among all people, together with a collection of raw materials, tools, implements, trial-pieces, models of furnaces, etc. On our visit to this museum, we were particularly struck with a collection of *failures*, or specimens showing what had been done to overcome faulty results, and what it was hopeless to attempt." ("Encyclopædia Britannica," eighth edition.) The principal painters of the French school did not then think it derogatory to their noble art to improve, by their occasional suggestions and designs, the embellishment of a coffee-cup or a dinner-plate. Raffaelle painted or gave designs for painting in enamel on glazed earthenware, and deigned to embellish a china dish. Mr. Brockedon saw a specimen of the latter description about the year 1833, in one of his Alpine excursions.

The manufacture at Sèvres has for several years been in a gradually advancing state, with regard to the whiteness, compactness, and infusibility of the body, the elegance of the form, the brilliancy of the colours, the elaborateness of the drawing, and the superb enrichments of the gilding. The *porcelaine dure* is formed of kaoline from the quarries near Limoges, alkali, sand, and nitre, to which, when in a state of fusion, clay is added. It requires a great fire to be hardened. What is called *biscuit de Sèvres* is this substance not enamelled. The paintings are executed upon the porcelain after it is hardened, and it then requires only a slight degree of heat to fix the colours and enamel. M. Bronguiart has successfully applied the pyrometer to the firing of porcelain after it is painted. The pyrometer is a kind of steelyard, with a needle placed at the extremity of a bar three feet in length. In the middle of this bar is a tube containing 29 inches of porcelain and 7 inches of silver. That end of the bar in which the silver is placed is introduced into the oven in which the porcelain is to be fired, and the heat, by dilating the silver, sets the needle in motion by means of a wheel at the extremity of the bar, and this shows the

degree of heat required. In firing porcelain, wood alone is employed. An ingenious method has also been discovered of printing the patterns upon porcelain, by which the execution is more perfect, and is effected in much less time. The beautiful *bleu de Sèvres*, the manner of obtaining which was supposed to be entirely lost, has been re-discovered by Bronguiart. A sort of sea-green ware, called *céladon*, has been produced. It somewhat resembles old Oriental ware. This *céladon* is a body-colour pervading the paste, and on it the French artists have succeeded in producing with a similar but white paste various designs, chiefly leaves and flowers, which stand out in gentle relief upon the vase or cup. The effect is very beautiful, especially in a variety of *céladon* which reflects local colour; by gas-light it is pink. The Sèvres manufactory has also produced majolica, and enamel on iron and copper; but its chief skill is in the higher kinds of figure-painting. The old Sèvres has likewise been produced in perfection, wonderfully like the original. The old Palissy ware and the ware of Henri Deux have also been reproduced. In a new species of ware, gold or silver is burnt into the enamel in considerable quantities, with very rich effect. Then the designs are painted on unfired enamels, the whole fired once for all; a large piece produces from £50 to £80, having the appearance of majolica. Sets of china printed from chromo-lithographs, even to the gold, are sold cheaply. The pure white china of Limoges is of great strength, although very thin and semi-transparent.

In Italy a factory was established at Deccia, near Florence, early in the last century. Venice also manufactured porcelain until 1812; but the most famous manufactory in Italy is the Capo di Monti, at Naples, founded by Charles III., in 1736. This sovereign appears to have exceeded the royal amateurs of Europe in his cultivation of the ceramic art, and he even surpassed Augustus III., who was nicknamed by Frederick of Prussia "the Porcelain King," from his having exchanged a whole regiment of dragoons for some huge useless china vases. Charles III. even worked in the factory with his own hands, and held an annual fair in front of the royal palace at Naples, where was a shop for the sale of the royal productions; and there was no more certain road to the king's favour than in becoming a purchaser. When Charles became King of Spain, he founded a factory at Madrid, which was destroyed by the French in 1812. His successor, Ferdinand, sanctioned the erection of other porcelain works, and even allowed the royal workmen to assist in their formation; they appear to have robbed the parent factory of its gold and silver models and other valuables.

The porcelain of Capo di Monti was not, as is commonly the case, an imitation of the art of some rival factory. Its beauty and excellence are due to the design, from shells, corals, embossed figures, etc., artistically moulded in high relief. Mr. Marryat regards the tea and coffee services of this ware as, perhaps, the most beautiful porcelain articles ever produced in Europe for transparency, thinness of the paste, elegance of form, and gracefully-twined serpent handles; as also for the delicate modelling of the ornamental groups in high relief, painted and gilt, contrasting well with the plain ground. Its manufacture was conducted with the greatest secrecy. The modelled figures of Capo di Monti ware are very life-like; whole scenes are wrought, all in one dull tint of stone, with nothing but the modelling to attract us. Nothing has ever been produced so life-like. If one could be quite sure as to the extent of the firing which they have undergone, it would be difficult to praise them too highly.

We have incidentally glanced at the prices paid for very fine porcelain, which are necessarily high, the material requiring to be treated with the precision of a chemical process, and the design and ornamentation demanding the highest skill. A Sèvres service of a good period has cost 30,000 livres. Mr. Minton received £1,000 for his service of turquoise and parian; the Marquis of Hertford gave £1,000 for two vases; and Lord Ward £1,500 for a dessert service of Sèvres. In the Bulteel collection of rare old porcelain, lately sold, were an old Chelsea vase and cover, which brought 355 guineas; an Oriental enamelled cistern, 295 guineas; old Sèvres cups and saucers, and plateaux, from 50 to 221 guineas; old Sèvres cabarets, 375 to 535 guineas; a pair of old Sèvres vases, 765 and 660 guineas; and three old Sèvres vases, 1,350 guineas. Such works as these belong, however, rather to the fine arts than the useful arts. A better taste has, however, grown more evident in pottery and porcelain for every-day use, as the people have become more familiar with the beautiful forms of antiquity, and art schools have been established; hence jugs sold for a few pence each are even of classic forms. Persons are no longer content with the barbarous style of ornament brought to this country from China; but a very great improvement has been made in multiplying copies of superior designs for transfer to the surface of the ware, by printing from cylinders a continuous sheet. The old "willow pattern" has descended from the dining-room to the kitchen, whence it has almost ejected the common white dinner plate. Meanwhile, a true taste for classic ornamentation is extensively cherished. The choice vessels of Etruria, Herculaneum, and Pompeii are imitated in Staffordshire, with copies of Roman pottery introduced into England more than two thousand years since. In articles of ornament we become familiarised with some of the finest works of Greek art, of which almost every chimney-piece bears evidence; whilst the grotesque vulgarities which delighted our forefathers are supplanted by fac-similes of sculptural triumphs that have been and will continue the admiration of ages.

We may here mention that the Porcelain Rock of China has recently been visited by Baron von Ricthópen, of Shanghai: it is situated in the King-te-chin district, where the Chinese have made nearly all their porcelain for about 3,000 years. He appears to show that the Chinese kaoline is not found under similar circumstances to the china clay of Cornwall and Devon. The porcelain rock of King-te-chin is stated to be of the hardness of felspar, and of a green colour like jade. The rock is reduced to powder, and made into bricks of two kinds, one being called "kaoling," and the other "retuntse," the supposed equivalent of Cornish china stone. The British porcelain clay, kaoline, exists as a soft imperfectly-formed variety of granite, and the china stone, "retuntse," is a more talcose rock.

The porcelain clay used in English works is obtained in Cornwall, and shipped in large quantities. The shipments in the year 1869 comprised 105,700 tons of kaoline, commonly called china clay; and 28,500 tons of china stone. Devonshire produced 56,200 tons of clay in 1869. 60,210 tons of clay were exported from Poole in the year, one-third of it for London, and nearly another third for America; the total being 2,000 tons more than in the preceding years.

Ceramic, the generic term including all manufactures of potter's clay, is derived from the Greek word for potter's clay. One of the quarters of the city of Athens, on the south-west side of the Acropolis, was called Ceramicus; and, although Pausanias assigns a different derivation, Pliny relates that it was so called from the manufactory of Choleostrius, a celebrated modeller of statues in clay.

PRINCIPLES OF DESIGN.—XI.

ART FURNITURE (*continued*).

BY CHRISTOPHER DRESSER, PH.D., F.L.S.

I FEAR that I have very feebly enforced and very inefficiently illustrated the true principles on which works of furniture should be constructed; and yet I feel that the structure of such works is of importance beyond all other considerations. Space is limited, however, and I must pass on; hence I must hope that I have induced the reader to think for himself, and if I have done so I shall have fulfilled my desire, for his progress will then be sure.

Respecting structure I have but a few general remarks further to make, and all these are fairly embraced in the one expression, "be truthful." An obvious and true structure is always pleasant. Let, then, the "tenon" and the "mortise" pass through the various members, and let the parts be "pinned" together by obvious wooden pins. Thus, if the frame of a chair-seat is tenoned into the legs, let the tenon pass through the leg and be visible on the outer side, and let it be held in its place by glue and wooden pins—the pins being visible. In this way that old furniture was made which has endured while piece after piece of modern furniture, made with invisible joints and concealed nails and screws, has perished. This is a true structural treatment, and is honest in expression also.

I do not give this as a principle applicable to one class of

furniture only, but to all. When we have "pinned" furniture with an open structure (see the back of Gillow's chair, Fig. 27), the mode of putting together must be manifest; but in all other cases the tenons should also go through, and the pins by which they are held in their place be driven from one surface to the other side right through the member.

In my first lesson on furniture (see page 311) I said that after the most convenient form has been chosen for an object, and after it has been arranged that the material of which it is to be formed shall be worked in the most natural or befitting way, that then the block-form must be looked to, after which comes the division of the mass into primary parts, and lastly, the consideration of detail.

As to the block-form, let it be simple, and have the appearance of appropriateness and consistency. Its character must be regulated, to an extent, by the nature of the house for which the furniture is intended, and by the character of the room in which it is to be placed. All I can say to the student on this part of the subject is this: Carefully consider good works of furniture whenever opportunity occurs, and note their general conformation. A fine work will never have strong architectural qualities—that is, it will not look like part of a building formed of wood instead of stone. There is but small danger of committing any great error in the block-form, if it be kept simple, and look like a work in wood, provided that the proportions of height to width and of width and height to thickness are duly cared for.

After the general form has been considered, the mass may be broken up into primary and secondary parts. Thus, if we have to construct a cabinet, the upper part of which consists of a cupboard, and the lower portion of drawers, we should have to determine the proportion which the one part should bear to the other. This is an invariable rule—that the work must not consist of equal parts; thus, if the whole cabinet be six feet in height, the cupboards could not be three feet while the drawers occupied three feet also. The division would have to be of a subtle character—of a character which could not be readily detected. Thus the cupboard might be 3 feet ·5 inches, and the drawers collectively 2 feet 7 inches. If the drawers are not to be all of the same depth, then the relation of one drawer, as regards its size, to that of another must be considered, and of each to the cupboard above. In like manner the proportion of the panels of the doors to the styles must be thought out; and until all this has been done no work should ever be constructed.

Next comes the enrichment of parts. Carving should be very sparingly used, and is best confined to mouldings, or projecting or terminal ends. If employed in mouldings, those members should be enriched which are more or less completely guarded from dust and injury by some overhanging member. If more carving is used, it should certainly be a mere enrichment of necessary structure—as we see on the legs and other uprights of Mr. Crace's beautiful sideboard, by Pugin (Fig. 34). I am not fond of carved panels, but should these be employed the carving should never project beyond the styles surrounding them, and in all cases of carving no pointed members must protrude so as to injure the person or destroy the dress of those who use the piece of furniture. If carving is used sparingly, it gives us the impression that it is valuable; if it is lavishly employed, it appears to be comparatively worthless. The aim of art is the production of repose. A large work of furniture which is carved all over cannot produce the necessary sense of repose, and is therefore objectionable.

There may be an excess of finish in works of carving connected with cabinet work; for if the finish is too delicate there is a lack of effect in the work. A work of furniture is not a miniature work, which is to be investigated in every detail. It is an object of utility, which is to appear beautiful in a room, and is not to command undivided attention; it is a work which is to combine with other works in rendering an apartment beautiful. The South Kensington Museum purchased in the last Paris International Exhibition, at great cost, a cabinet from Fourdonois; but it is a very unsatisfactory work, as it is too delicate, too tender, and too fine for a work of utility and furniture—it is an example of what should be avoided rather than of what should be followed. The delicately-carved and beautiful panels of the doors, if cut in marble and employed as mere works of sculpture, would have been worthy of the highest commendation; but works of this kind wrought in a material that has a "grain," however little the grain may show, are absurd. Besides, the subjects are of too pictorial a character for "applied works"—that is, they are treated in too pictorial or naturalistic a manner. A broad, simple, idealised treatment of the figure is that which is alone legitimate in cabinet work.

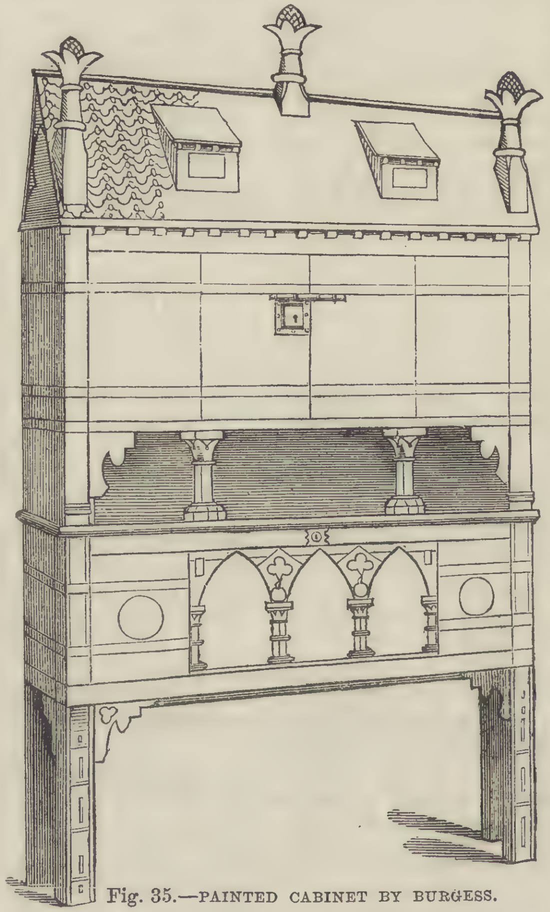


Fig. 35.—PAINTED CABINET BY BURGESS.

Supports or columns carved into the form of human figures are always objectionable.

Besides carving, as a means of enrichment, we have inlaying, painting, and the applying of plaques of stone or earthenware, and of brass or ormolu enrichments, and we have the inserting of brass into the material when buhl-work is formed.

Inlaying is a very natural and beautiful means of enriching works of furniture, for it leaves the flatness of the surface undisturbed. A great deal may be done in this way by the employment of very simple means. A mere row of circular dots of black wood inlaid in oak will often give a very good effect; and the dots can be "worked" with the utmost ease. Three dots form a trefoil, four dots a quatrefoil, six dots a hexafoil, and so on, and very desirable effects can often be produced by such simple inlays.

Panels of cabinets may be painted, and enriched with ornament or flatly-treated figure subjects. This is a beautiful mode of enrichment very much neglected. The couch (Fig. 30) I intended for enrichment of this kind. If this form of enrichment is employed, care should be exercised in order that the painted work be in all cases so situated that it cannot be rubbed. It should fill sunk panels and hollows, and never appear on advancing members.

I am not fond of the application of plaques of stone or of earthenware to works of furniture. Anything that is brittle is not suitable as an enrichment of wood-work, unless it can be so placed as to be out of danger.

Ormolu ornaments, when applied to cabinets and other works

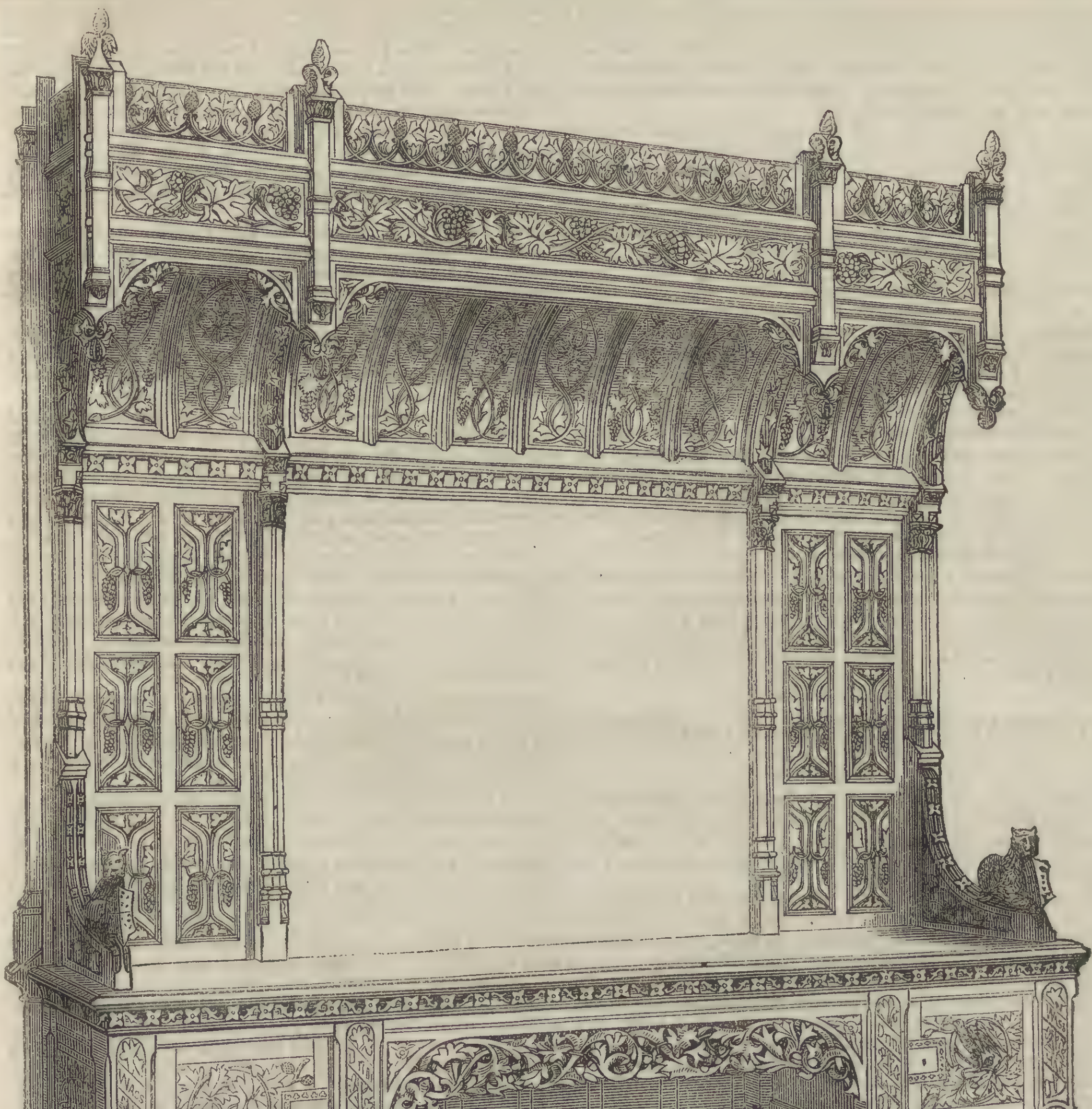


Fig. 34.—CARVED SIDEBOARD BY CRACE, FROM DESIGN BY A. WELBY PUGIN.

of furniture, are also never very satisfactory. They look too separate from the wood of which the work is formed—too obviously applied; and whatever is obviously *applied* to the work, and is not a portion of its general fabric, whether a mass of flowers carved in wood, or an ormolu ornament, is not pleasant.

Buhl-work is often very clever in character and skilfully wrought, but I do not care for it. It is of too laborious a character, and thus intrudes upon us the sense of labour as well as that of skill. As means of enrichment, I approve of carving, sparingly used, of inlays, and of painted ornament in certain cases; and the just employment of these means is capable of securing the utmost beauty in cabinet-work. Ivory inlaid with ebony is very beautiful.

In conjunction with this article, we engrave a sideboard executed by Mr. Crace, from the design of Mr. A. Welby Pugin, to which I have before alluded (Fig. 34), and a painted cabinet by Mr. Burgess (Fig. 35), the well-known Gothic architect, whose architecture must be admired. Both of these works are worthy of study of a very careful kind.

In the sideboard, notice first the general structure or construction of the work, then the manner in which it is broken up into parts, and lastly, that it is the structural members which are carved. If this work has faults, they are these: first, the carving is slightly in excess—thus, the panels would have been better plain; and, second, in some parts there is a slight indication of a stone structure, as in the buttress character of the ends of the sideboard.

To the cabinet much more serious objections may be taken.

1. A roof is a means whereby the weather is kept out of a dwelling, and tiles afford a means whereby small pieces of material enable us to form a perfect covering to our houses of a weather-proof character. It is very absurd, then, to treat the roof of a cabinet, which is to stand in a room, as if it were an entire house, or were to stand in a garden.

2. The windows in the roof, which in the case of a house let in light to those rooms which are placed in this part of the building, and are formed in a particular manner so as the more perfectly to exclude rain, become very absurd when placed in the roof of a cabinet. These, together with the imitation tiled roof, degrade the work to a mere doll's-house in appearance.

3. A panelled structure, which is the strongest and best structure, is ignored; hence strong metal bindings are necessary.

The painting of the work is highly interesting, and had it been more flatly treated, would then have been truthful, and would yet have lent the same interest to the cabinet that it does now, even if we consider the matter from a purely pictorial point of view.

VEGETABLE COMMERCIAL PRODUCTS.

XIV.

DYE PLANTS (*continued*).

INDIGO (*Indigofera tinctoria*, L.; natural order, *Leguminosæ*).—A shrub from two to three feet high, with pinnate leaves, and racemes of greenish-coloured flowers, marked with vermilion red. Indigo is also extracted from two other species, viz., *Indigofera anil* and *I. cærulea.*

This plant is a native of India, whence our chief supplies are received. It is principally grown in Bengal, from 20° to 30° N. latitude. Indigo is also cultivated in Java, the Philippine Islands, Egypt, the West Indies, and British Honduras.

The best time for cutting the plant is when it begins to flower, because then it is always richest in its peculiar secretions. The plants, when cut, are first laid in a vat, called the steeper, about twelve or fourteen feet long and four feet deep, and filled with water. In twelve or sixteen hours the water begins to ferment, swell, and grow warm; the highest point of its ascent is marked, for when it ceases to swell fermentation begins to abate. The manager now opens a tap to let off the water into a second vat, called the beater, and the gross sediment at the bottom of the first one is carried off and used as manure for the next crop of plants, for which purpose it is excellent. The indigo fluid received into the second vat is kept actively stirred and beaten with bamboos until it begins to granulate. When granulated sufficiently, the liquor assumes a deep purple colour, the whole being troubled and muddy. It is now allowed to settle, and as the upper part of the water clears, it is removed into other vessels, until nothing remains but a thick sediment at the bottom of the vat. This is put into gunny bags, which are hung up to dry. To finish the drying, the indigo is turned out of the bags, exposed to the sun, worked upon boards with a spatula, and put into boxes, and again exposed to the sun until fully dried, when it is ready for market.

The indigo plant grows best in the East Indies. It was first brought to Europe by the Dutch in the middle of the seventeenth century. It is now imported, every year in increasing quantities, from the East Indies, and also from both North and South America, to which it has been transplanted. Indigo is used in the dyeing-houses of our woollen, linen, cotton, and silk manufacturers, and has almost completely displaced the native woad (*Isatis tinctoria*, L.) formerly used. The finest sort comes from Bengal, *viâ* Calcutta. About 5,000 tons are yearly imported; and British India has almost a monopoly of the indigo trade. The French import a very good quality from the Isle of Bourbon, and the Dutch from the Sunda Islands, in the East Indies. The best American indigo is raised in Guatemala, in Central America, and an inferior kind at Caracas, in Brazil, St. Domingo, Carolina, and Louisiana. There are extensive indigo plantations on the fertile delta of the Nile, under the management of Hindoos. Indigo has also been received recently in small quantities from Madeira, the river Senegal, and Sierra Leone.

Good indigo is known by the purity of its colour and its lightness, which is indicative of the absence of any earthy impurity. A blue carmine, made out of this substance, is a very high-priced colour, used by painters. The quantity of indigo imported in 1868 into the United Kingdom was 75,874 cwt.

TURMERIC (*Curcuma longa*, L.; natural order, *Zingiberaceæ*).—This is a stemless plant, with palmated tuberous roots of a deep orange colour internally, long-stalked, lanceolate, smooth leaves, and flowers in a central oblong green spike.

Turmeric is a native of the warm parts of Asia, and is found in India, China, Cochin-China, Java, and Malacca, where it is extensively cultivated for the sake of the beautiful yellow dye afforded by its root, and also as a condiment, as it forms a principal ingredient in Indian curry-powder. Turmeric gives a beautiful but fugitive gold colour to silks. Paper stained with turmeric is much used by chemists as a test for alkalies, which colour turmeric paper reddish or brownish. Turmeric is also used in making Dutch pink and gold-coloured varnish. There are several varieties of this dye in the market, the principal of which are the Long Turmeric (*Curcuma longa*, L.), and the Round, better known as Chinese turmeric. In 1851, the imports of turmeric into the United Kingdom from China and India were about 2,000 tons.

QUERCITRON (*Quercus tinctoria*, Michx.; natural order, *Cupuliferæ*).—This oak grows from sixty to ninety feet high. Its leaves are six to eight inches long, obovate, deeply sinuate-lobed, pubescent beneath; the acorn small ovoid, seated in a sub-sessile cup, which tapers at the base.

This tree is indigenous to the United States, growing abundantly in Pennsylvania, North and South Carolina, and Georgia. The inner bark is an article of commerce under the name of quercitron, and furnishes a yellow dye, which has now nearly superseded the use of our indigenous weld (*Reseda Luteola*, L.) in calico printing. Quercitron, when crushed, resembles a mass of short yellowish-white fibres, mixed with powdery particles, and in this state is sent over in casks. From 3,000 to 4,000 tons are annually received in England from New York, Philadelphia, and Baltimore.

YELLOW BERRIES (*Rhamnus infectorius*, L.; natural order, *Rhamnaceæ*).—This plant is a species of buckthorn, and is a native of Persia, Turkey, and the south of Europe. It is a procumbent shrub, growing naturally in rough, rocky places. The unripe berries furnish a yellow dye, which is largely employed in calico printing, for dyeing morocco leather and paper, as well as for the preparation of sap green and Dutch pink. The largest and best yellow berries are the Persian, which come to this country *viâ* Aleppo and Smyrna; a considerable quantity is also received from France and Turkey. The importation amounts annually to between 500 and 600 tons.

FUSTIC (*Maclura tinctoria*, Nutt; natural order, *Urticaceæ*).—A large and handsome evergreen tree, growing in the West Indies and tropical America. There are large forests of this tree in the Antilles, especially in Jamaica, Cuba, Porto Rico, and Tobago. Fustic is brought to market in long pieces or logs. The beautiful yellow and red veined is the best. Fustic dyes yellow, olive, brown, maroon, bronze, and Saxon green. The quantity imported into England in 1851 was 9,808 tons.

WOAD (*Isatis tinctoria*; natural order, *Cruciferæ*).—Woad is much cultivated in France, Normandy, Alsace, and also in Germany, where it was in use a thousand years ago. It is indigenous to England and Germany. The blue matter of this plant is contained in its leaves. Woad was used by the ancient Britons to stain their bodies. The extensive use of East Indian indigo has greatly restricted the cultivation of woad; but as the dyers very unwillingly dispense with it, on account of its cheapness and the durability of its colour, it is probable that indigo will never entirely supersede its use.

NICARAGUA OR PEACH WOOD (*Cæsalpinia echinata;* natural order, *Leguminosæ*).—This dye-wood gets its name from the republic of Nicaragua, in Central America. It reaches this country in blocks about four feet in length and eight inches in diameter. It dyes a delicate peach and cherry colour, and is much used. We receive annually about 8,000 tons. That which comes from Peru yields the finest shades of colour.

Several other species of *Cæsalpinia* yield dye-woods. Thus *Cæsalpinia crista* furnishes the Brazil wood, and *Cæsalpinia Brasiliensis* the Brazilletto wood, which yields some very fine rose-coloured, yellow, and orange-red dyes, according to the mordants used. About 800 tons of the first and 400 tons of the latter annually arrive in England from the vast forests of South America, which are very rich in dye-woods. Brazil wood is imported principally from Pernambuco, and is also known by the name of Fernambuk wood, in allusion to the place of importation. Besides its usefulness as a dye-wood, it also serves for objects of art; bows of violins are especially made from Fernambuk wood.

SAPAN WOOD OR BUKKUM WOOD (*Cæsalpinia Sapan*) furnishes another good red dye, which is used extensively both in India and Europe. About 3,670 tons were imported into England in 1850 from the East Indies.

RED SANDERS WOOD (*Pterocarpus santalinus*, L.; natural order, *Leguminosæ*) yields a dye of a bright garnet-red colour, and is chiefly employed for dyeing wood. The tree which produces the wood is a lofty one, common about Madras and other parts of India. The exports of this wood from Madras in one year only have been nearly 2,000 tons. We import also usually between 700 and 800 tons a year from Calcutta and Bombay.

COLOUR.—VIII.

By Professor CHURCH, Royal Agricultural College, Cirencester.

APPLICATIONS OF PRINCIPLES OF TRIPLE DISTRIBUTION, BALANCE, AND QUALITY IN ESTIMATING THE AGREEABLENESS OF CERTAIN ASSORTMENTS OF COLOUR.

WE may now proceed to illustrate by a few examples the application of the principles of the distribution, balance, and quality of colours to the triple assortments named in the last lesson, which were of three series.

SERIES I.—*Assortments of two primary colours* with white, grey, or black constitute the first series. They are generally preferable to assortments in which one primary and one secondary colour occur, unless these happen to be complementary, when the effect is more agreeable still. The more brilliant colour must be used in moderation, and may be distributed in narrow lines or delicate forms. The deeper colour usually requires a broader treatment, and to be present in larger quantity. In separating the two bright primaries, yellow and red, from each other, black is preferable to white; while in separating blue and red, white is preferable to black. In such instances we have to pay attention to the balance of tone, and must not allow the bright or the deep elements of colour to preponderate. Grey is very often of use in colour assortments, where white or black might produce too marked a contrast.

SERIES II.—*Assortments of one primary and one secondary colour* with white, grey, or black. It is needless to say that in the cases belonging to Series II. the effect of a primary with its complementary secondary is far superior to all the other combinations. Thus yellow and violet constitute a more agreeable assortment than yellow and orange. But yellow and violet cannot be much improved by the introduction of black, which too much resembles the violet, and differs too much from the yellow; while white is liable to objection precisely the converse of this. Nor does grey produce a very satisfactory effect in this arrangement. The more agreeable the combination of two colours when in contiguity the less improvement do they require, and the less do they experience from the introduction of white, grey, or black. Such assortments as that of yellow and orange are, on the other hand, greatly improved by the introduction of another element to define or emphasise them. The arrangement yellow, black, and orange is vastly superior to that with yellow and orange alone. When white is used in an assortment of this nature containing two bright colours, it often produces a happier effect when introduced so as not to separate the colours, but to precede the brighter of them—thus, white, yellow, orange. If white be also inserted between the yellow and the orange, the effect is impoverished. When two deep colours are used together, and in combination with black, the black may advantageously follow the deeper colour, but such an assortment as violet, blue, and black is a sombre one; yet to many eyes it will appear more satisfactory than one in which alternate spaces of white are introduced, in order to restore the balance of tone.

SERIES III.—*Assortments of Two Secondary Colours.*—Orange and green may be advantageously separated by black, orange and violet by grey, and violet and green by white.

We hope the examples just given will be sufficient to enable our readers, with the aid of actual experimental trials, to judge of the merit of any triple assortment of colour, and to arrange many agreeable combinations suitable for special purposes. We may just allude here to one of the applications flowing out of the principles which we have been enunciating. It is an application of great service to ornamental designers, and has been extensively carried out into practice. It may be briefly stated in three rules or propositions:—1. If in an ornamental design the ground be of a deep tone of colour, and the forms or figures upon it be of a less intense or lighter complementary colour, then these forms should be outlined with white, or with a light tone of grey, or, in any event, with some colour of a tone lighter either than the ground or the pattern. 2. If in an ornamental design the ground be of a light tone of colour, and the forms or figures upon it be of a more intense or deeper complementary colour, then these forms should be outlined with black, or with a deep tone of grey, or, in any event, with some colour of a tone deeper than either the ground or pattern. 3. In painting with tones of one colour, or monochrome, the same rule must be observed, varying the depth or tone of the outline according to the relations as to tone of the pattern and the ground, as in the preceding rules.

TECHNICAL DRAWING.—XXVI.

MECHANICAL DRAWING (*continued*).

CAMS.

CAMS are variously-formed plates, or grooves, by means of which a circular may be converted into a reciprocating motion.

The circular motion being uniform, the reciprocating motion may also move uniformly as a sliding-bar; or its velocity may be varied at pleasure.

The Heart-shaped Cam.—The form of this cam is delineated by means of a double Archimedes' spiral, the construction of which is given in Fig. 247.

Let 12 XII be the widest limit of the required spiral.

Describe a circle with 12 XII as a radius.

Divide this circle into any number of equal parts as I to XII, and draw radii.

Divide one of the radii into a corresponding number of equal parts, as 1 to 12.

From the centre, with radius A 1, describe an arc cutting the radius I in B.

From the centre continue describing arcs, with radius 2, 3, etc., cutting the radii II, III, etc., in C, D, E, etc.

From 12 trace a curve passing through these points, which will be the spiral required.

Fig. 248 is an example of the *heart-shaped cam.*

Let a a' be the rectilinear distance to be traversed, and O the centre of the shaft, on which the cam is fixed.

It is required to make the point a advance to a' in a uniform manner, during a semi-revolution of the shaft, and to return it to its original position in the same manner during a second semi-revolution.

From the centre O, with the radii O a and O a', describe circles; divide the outer one into any number of equal parts; divide the line a a' into the same number of parts.

From O, with radius O 1, O 2, O 3, etc., describe circles cutting the radii correspondingly numbered, and thus the points A, B, C, D, etc., will be obtained. The curve drawn through these points will be the spiral form for the cam required to raise the point a to a'.

But it is not possible to employ a mathematical *point* in practice, since "a point is that which has position but not magnitude." Therefore, an anti-friction roller, which has its centre where the point would be, is employed, and in consequence of

this, the size of the cam has to be reduced from that of the original curve to allow for the size of the roller.

To accomplish this, with the radius of the anti-friction roller describe arcs from A B, C D, etc., and draw the curve which is to form the outline of the cam to touch the highest point of these arcs. Observe that the highest point would not be on the

Cams of small size are simply flat discs of the shape required. When large, they are formed with a crown or rim, B′, of equal thickness all round; a boss, C (by means of which it is keyed on to the shaft D), and arms, E, F, G. These are strengthened internally by a feather or web, G G.

The line of this web is, in the first place, parallel to the rim,

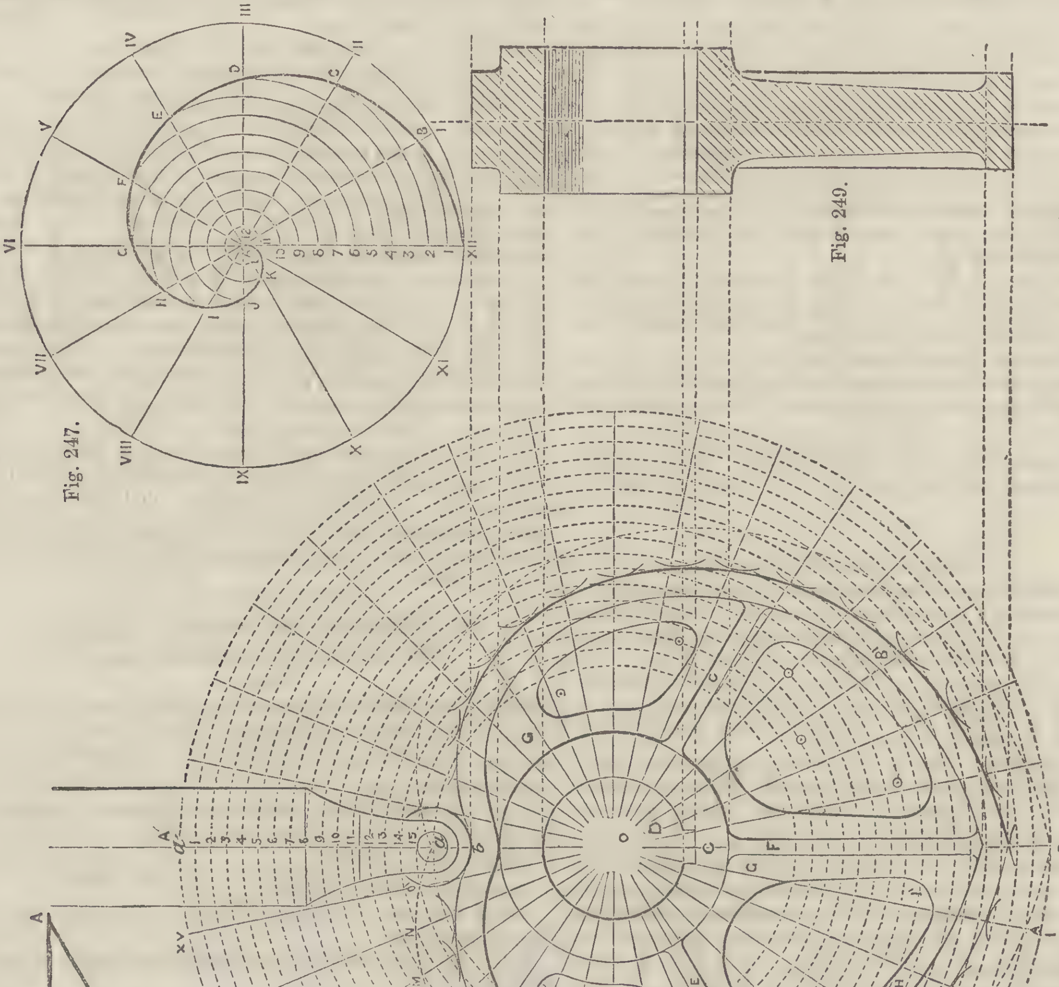


Fig. 247. Fig. 248. Fig. 249. Fig. 250.

radii; for example, it would not be at g, but on a line perpendicular to the curve at G—viz., at h.

This form of cam is symmetrical to the line a which passes through its centre—in other words, the first half which pushes the roller; and consequently the rod A′, to the end of which the roller is fitted, from a to a', is precisely the same as the second half, with which the roller keeps in contact during the descent of the roller from A′ to a. Thus a regular alternating motion is given to the roller by the circular motion of the cam.

curves into the part strengthening the arms, becomes wider as it nears the boss, and is then united to the adjoining web by an arc—as at I′—or returns into the outer portion by an arc—as at J′.

It may here be remarked that the centres, from which these uniting arcs are struck, are shown on the one side. The inner curve of the rim and that of the web are obtained in the same manner as the external form of the cam was deduced from the original spiral.

Fig. 249 is a vertical section of the cam through the centre of the shaft and the arm F.

In machines for crushing or pounding, cams in the involute form are generally used. In such cases the curve would not be a double one, its office being to raise the stamp or pestle to a given height, and then letting it fall by its own weight upon the substance to be crushed, as in a stamping-mill; or to be beaten, as in a forge-hammer.

THE SCREW.

If a piece of paper of the form of a right-angled triangle (A B C, Fig. 250) be rolled round a cylinder, the hypothenuse, or long side, A C, of the triangle will generate a curve, winding round the cylinder like a corkscrew. This is called the *helix*, and it is this curve which forms the thread of a screw.

The elementary steps in the construction of the helix are given in a previous lesson (page 301), and it is intended here to adapt the system to the projection of screws.

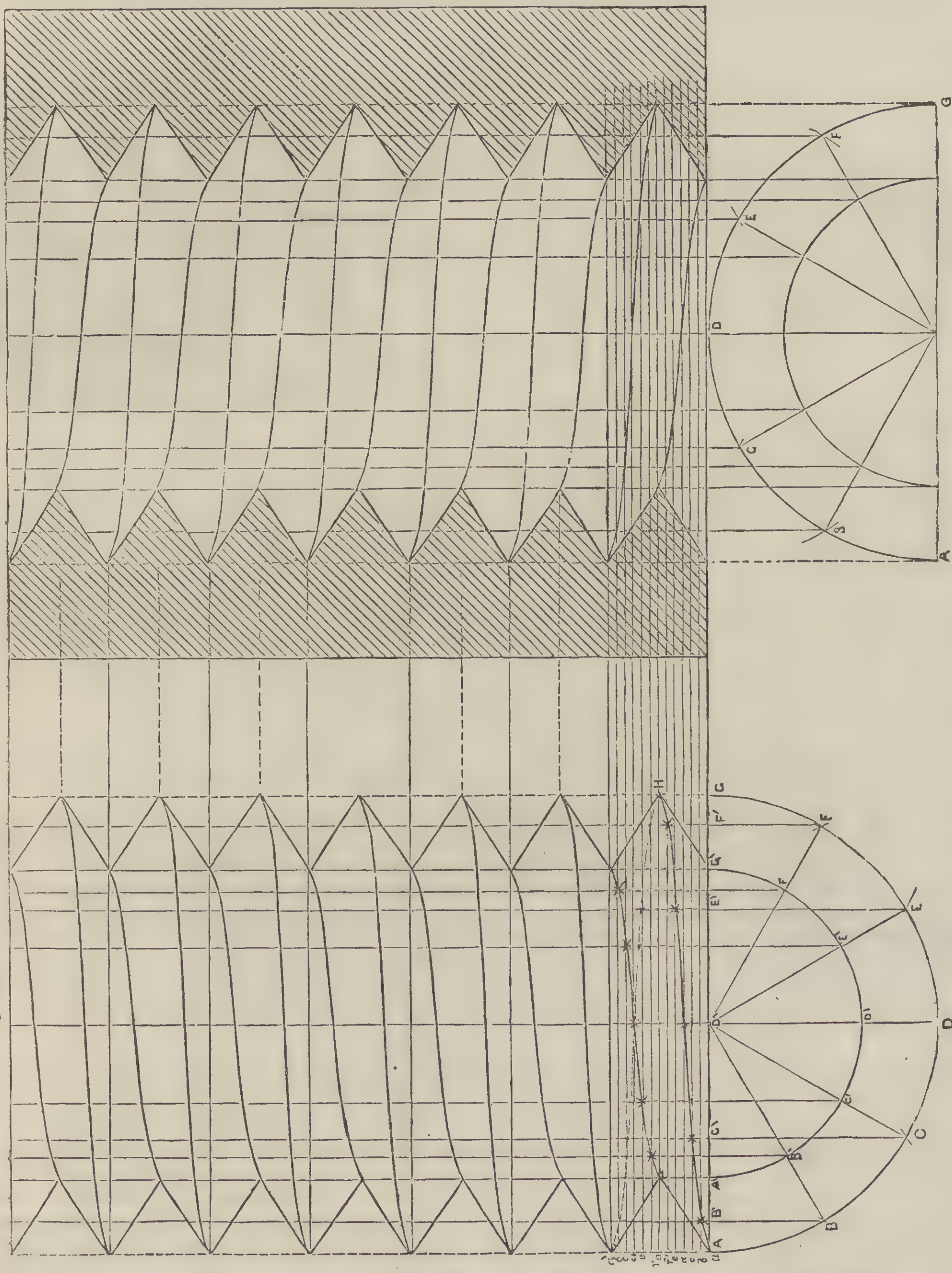


Fig. 254. Fig. 253. Fig. 252. Fig. 251.

Screws are cylindrical pieces of wood or metal, in which helical grooves are cut; the ridge left standing is called the *thread*. The groove and thread together are called the *pitch*, which, as in the teeth of wheels, corresponds with the distance from the centre or edge of one thread to that of the next.

The screw then consists of two cylinders—the inner being the deepest part of the groove, and the outer being the highest part of the thread; the larger one representing the cylinder before

the grooves are cut; the other, the cylinder as it would be if the thread were completely turned off.

Screws are named according to the form of their thread—as V (or angular-threaded), square (or round-threaded).

Screws, as a matter of course, work in an aperture corresponding with the thread and grooves of the screw; this is called the *nut*, or *matrix*.

Fig. 251 is the half-plan of a V-threaded screw. The larger semicircle represents the outer, and the smaller one the inner cylinder already spoken of.

Divide these into any number of equal parts, as A, B, C, D, etc., and draw radii.

Now, devoting the attention for the present to the projection of the edge of the thread, the outer semicircle only is used.

From A and G (Fig. 251) draw perpendiculars, which will give the elevation of the outer cylinder (Fig. 252).

Now set off at A the height of a pitch, $a\ a'$, and divide it into a number of parts corresponding with those into which the circle has been divided—viz., a, b, c, d, etc.

From each of these points draw horizontals, and from the points correspondingly lettered in the plan, raise perpendiculars; these intersecting, will give the points, × × ×, through which the helix forming the thread of the screw is to be traced.

The helix for the bottom of the groove is to be projected similarly. The curve, however, must start from the horizontal g; that is, midway between a and a'.

When the first curve has been drawn, and the starting-points for the threads on the inner and outer cylinders have been found, the curves throughout may, for convenience, be drawn by means of a templet. This, however, is only to be used as a ruler, to draw the lines by mechanical means when the points have been duly projected. The draughtsman having acquired the power of drawing the curves by hand, may avail himself of the templet for expedition in making the drawings required for business purposes.

To make these templets (say the larger one), draw a straight line on a piece of veneer, and on this, starting from A, erect the perpendiculars, B′, C′, D′, E′, F′, and G.

Let the height of G be equal to G H, and make the height of each of the others correspond with the height of the intersections × × ×. Trace the curve most carefully by hand, cut it out with a penknife, and finish with fine glass-paper, slightly rounding the edges on both the front and back, so that the same templet may be used on either side. It is scarcely necessary to remark that the templet may be as wide below the line A G as may be convenient.

The V form of the thread is obtained by joining the interior angle of the groove with the angle of the thread of the screw.

Fig. 253 is the plan and Fig. 254 is the sectional elevation of the nut for this screw. It is projected in precisely the same manner, the reverse curves being strengthened. Figs. 252 and 253 may be projected simultaneously when both plans have been drawn, as the horizontals a, b, c, d, etc., may be carried across, and so serve for both figures.

APPLIED MECHANICS.—IX.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

THE STEAM-HAMMER AND ROLLING-MILLS.

We commence in the present lesson a short account of the machinery which is used in iron-working. Foremost among the tools used in this manufacture is the steam-hammer, the invention of Mr. James Nasmyth. This machine has enabled forgings to be accomplished with facility which without its aid would have been completely impossible; in fact, it has effected a complete revolution in the working of wrought-iron.

Before the introduction of Nasmyth's patent, the only assistance which steam had given to human labour in forging was the helve or tilt-hammer, which is still extensively used for certain classes of work. After pig-iron has been puddled, the "blooms," as the masses of iron are termed while still white-hot from the puddling furnace, are dragged to the "helve." The helve is shown in Fig. 1. It is, in reality, a lever of the first order. In the centre is the fulcrum about which the hammer turns; at one end is the heavy mass which forms the head of the hammer; at the other the power is applied; this consists of a cam (p. 408), which, by its revolutions, raises the lever, and then allows it to fall; under the head of the hammer is the anvil, on which the bloom is placed. A blow is given with every revolution of the cam, and the intensity of the

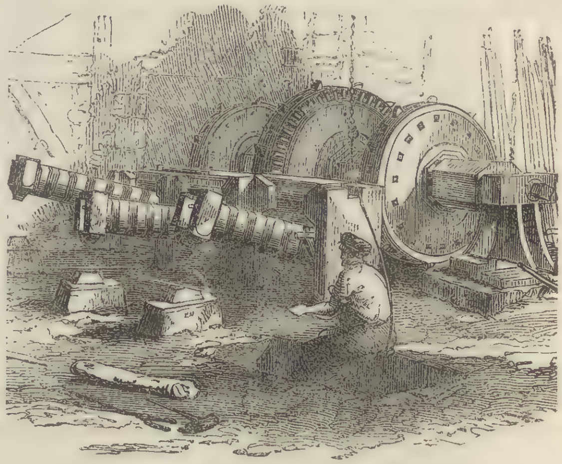


Fig. 1.—THE HELVE OR TILT HAMMER.

blow depends upon the height to which the head of the hammer is raised. Sometimes the fulcrum is at one end of the helve, and the power is applied at the centre. In this case the machine is a lever of the first order.

The magnitude of the blow which can be given by the helve, when a lever of the first order, will be understood from the accompanying figure (Fig. 2). Suppose A be the fulcrum, and that a weight at B is raised up to C, moving in the arc of a circle; the actual height to which B is raised is measured by the perpendicular C P. The number of units of work expended in raising the weight is—

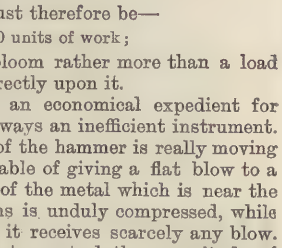
$$W \times CP,$$

where W is the number of pounds in the weight, and C P the number of feet in the line C P. Thus, for example, if C P were 2 feet and W 500 pounds, the product would be—

$$2 \times 500 = 1{,}000 \text{ foot-pounds.}$$

By the principle of work which we have already explained, the blow must perform as many units of work in its effect as was originally given to it; hence the blow must effect 1,000 units of work upon the bloom submitted to it in the case we have supposed. Suppose the bloom, which may be a mass seven or eight inches thick, receive a compression of half an inch from a single blow, then the helve must exert a sufficiently great pressure throughout that half-inch to expend all the 1,000 units of work. The pressure must therefore be—

Fig. 2.



$$24 \times 1{,}000 = 24{,}000 \text{ units of work;}$$

thus the helve compresses the bloom rather more than a load of ten tons would do if placed directly upon it.

The helve, though useful as an economical expedient for saving human labour, is in many ways an inefficient instrument. In the first place, since the head of the hammer is really moving in the arc of a circle, it is incapable of giving a flat blow to a large piece of work; the portion of the metal which is near the hinge about which the helve turns is unduly compressed, while that which is furthest away from it receives scarcely any blow. It is also not found practicable to control the magnitude of the blow, which is, therefore, always of the same magnitude. These circumstances have led to the invention of the steam-hammer, shown in Fig. 3.

A A are two upright supports of cast-iron; D is an inverted cylinder in which a piston moves; this piston is attached to

the rod E, which passes through a stuffing-box in the usual manner. To the end of the piston the hammer-head, F F F, is attached. As the piston rises and falls the hammer-head moves up and down between the vertical guides. The piston-rod is attached to the hammer by an elastic packing of wood, the object being to protect the piston-rod from the effect of the blows which the hammer delivers.

The hammer in Nasmyth's original invention is allowed to fall by its own weight; the only object of the steam is to raise it. It is, therefore, only necessary to provide for the admission of steam to the lower part of the cylinder when the hammer is to be raised, and to allow it to escape when the hammer is to fall. In order, however, to control the action of the hammer with facility, and to render it self-acting when necessary, several very ingenious contrivances have been introduced, a description of which will be necessary.

At the bottom of the cylinder is a slide-valve, included in the box J. When in one position this valve admits steam to the bottom of the cylinder, and when it is moved to the other position it opens communication between the bottom of the cylinder and the external air. The rod which moves this slide is shown at L L; the other end of this rod contains a piston which slides in the cylinder M. This cylinder is called the steam-spring; it is always provided with steam in its upper part by a pipe which leads from J. Thus the constant effect of the steam is to keep the rod L and the slide-valve attached to it pressed down, and thus to keep the hammer raised. In order, therefore, to allow the hammer to fall, the rod L L must be forced upwards against the steam in the spring M. This can be done by depressing the rod P P, which is under the control of the workman in charge of the machine. When the valve is raised, the cylinder is placed in communication with the air, and the supply of steam is stopped; the consequence of this is that the hammer falls and delivers a blow upon the mass placed on the anvil, the magnitude of which depends both upon the weight of the hammer and the distance through which it falls.

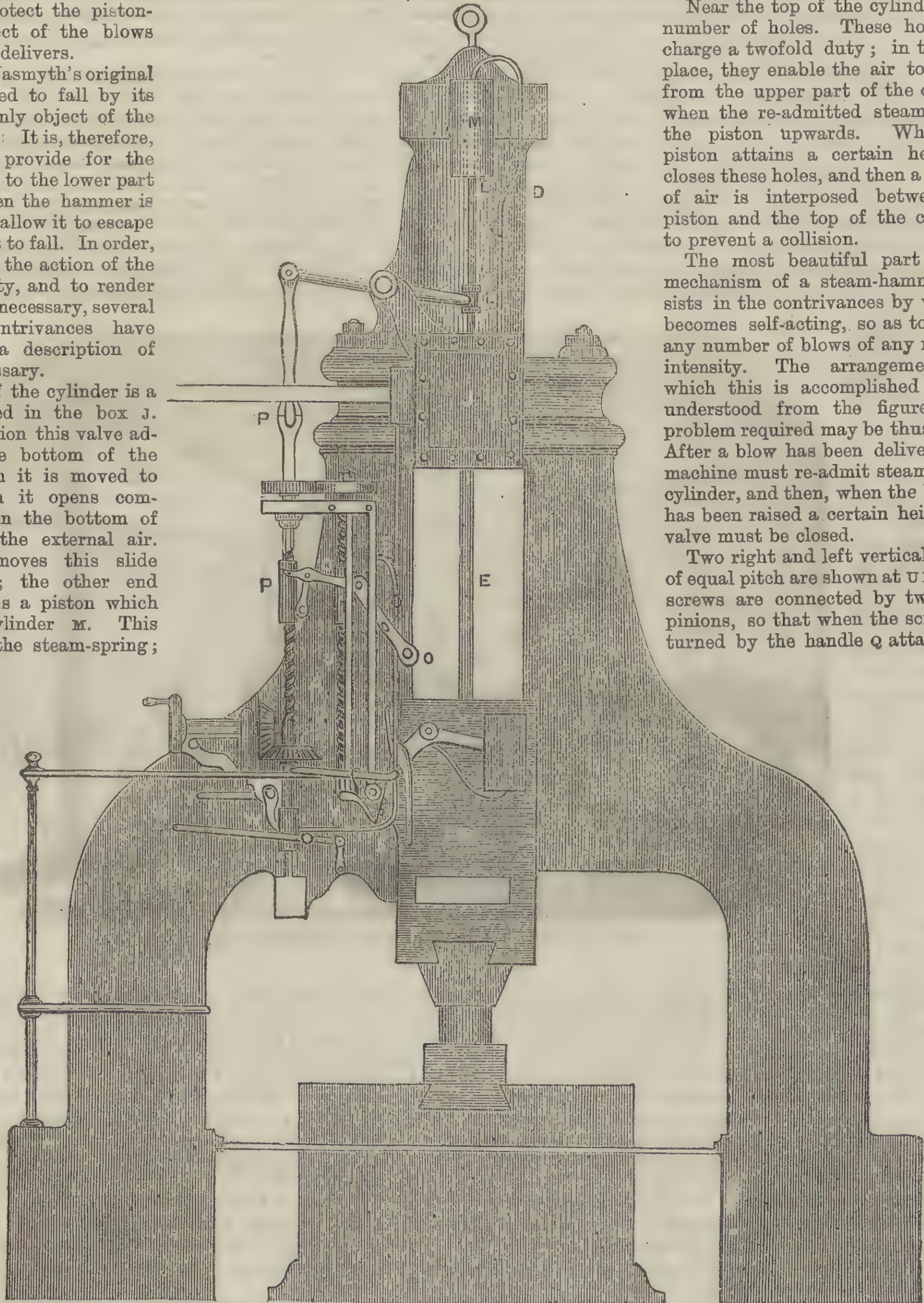


Fig. 3.—THE STEAM HAMMER.

Near the top of the cylinder are a number of holes. These holes discharge a twofold duty; in the first place, they enable the air to escape from the upper part of the cylinder when the re-admitted steam forces the piston upwards. When the piston attains a certain height it closes these holes, and then a cushion of air is interposed between the piston and the top of the cylinder, to prevent a collision.

The most beautiful part of the mechanism of a steam-hammer consists in the contrivances by which it becomes self-acting, so as to deliver any number of blows of any required intensity. The arrangements by which this is accomplished will be understood from the figure. The problem required may be thus stated. After a blow has been delivered, the machine must re-admit steam to the cylinder, and then, when the hammer has been raised a certain height, the valve must be closed.

Two right and left vertical screws of equal pitch are shown at U E; these screws are connected by two equal pinions, so that when the screw P is turned by the handle Q attached to the bevelled wheels, the two screws are turned with equal velocities in opposite directions, and thus the nuts are made to move parallel to each other with equal velocities. The bevelled wheel upon P slides upon it, but is prevented from turning round upon it by a feather; this is to enable the screw P P to be depressed without altering the position of the bevelled wheel. The nuts upon the screws carry the lever O O, at the extremity of which a small roller, O, is placed; now, by turning the handle at Q, the

roller O can be placed at any height along the guides between which the hammer-head moves. When the hammer in its ascent encounters this roller, it forces it upwards; this depresses the end of the bent lever which turns on a fulcrum on the screw U, depresses P P, and closes the steam-valve. With this arrangement alone, however, the hammer could not fall to the anvil, for the moment it began to descend the action of the steam spring would open the valve, and restore the levers to their original position. An arrangement has, therefore, to be provided by which the rod D must be held up against the steam spring during the descent of the hammer. There is an enlargement upon the screw-shaft P, a little below the bevelled wheel, and there is a small trigger which, when the screw is forced downwards, drops upon the narrow portion of the shaft, and detains the screw in its depressed condition. It follows, therefore, that when the hammer has raised O, the steam-valve is permanently shut until the trigger is drawn back. An ingenious arrangement enables the hammer itself to disengage the trigger the moment the blow is struck. A piece called the latch, X, is attached to the hammer head; it is usually kept in position by a spring, but when the descent of the hammer is suddenly checked by the delivery of the blow, the inertia of the latch X carries it forward, and the end of the latch *kicks* against a piece, S S. The piece S S is capable of moving like one side of a parallel ruler; it transmits the pressure to a piece V, which then pushes back the trigger W, and allows the ascent of the screw P. In this way the hammer will deliver blow after blow, and the action is at once arrested by the attendant raising the handle at Y; the hammer then oscillates backwards and forwards, giving time for the adjustment of the work. The actual form of the steam-hammer when in use is shown in Fig. 4.

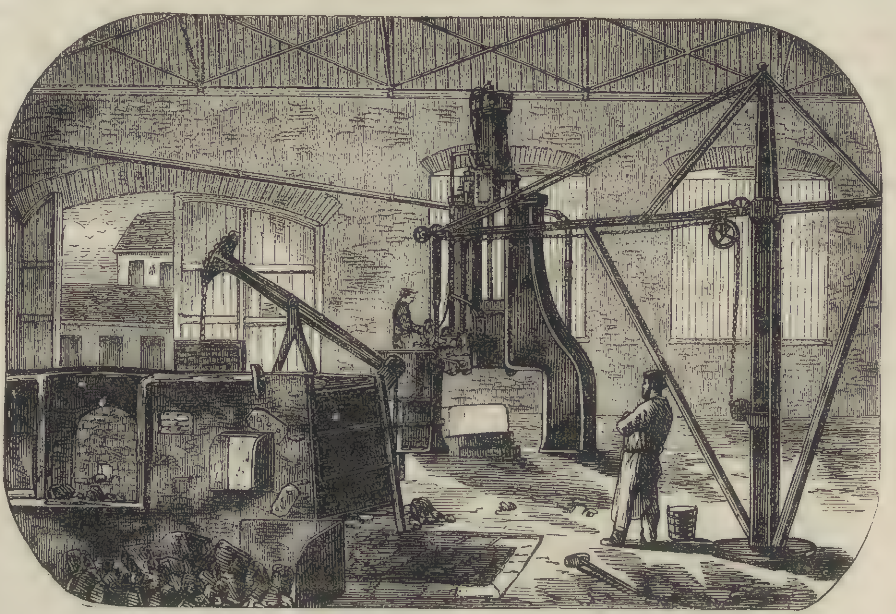


Fig. 4.—STEAM FORGING WITH NASMYTH'S HAMMER.

In the manufacture of wrought iron and steel, the rolling-mills are of not less utility than the steam-hammer. The ordinary bar and rod iron, which is used for such multitudes of purposes, is produced by rolling; and heavier masses, such as iron plates, railway lines, or armour-plating for ships, are also manufactured by the rolls. We shall commence our description of the rolling-mills by a brief account of the manner in which railway bars are made from Bessemer steel.

The Bessemer steel, after having been cast in large ingots from the "converter," soon solidify; as soon as they are set, though still brilliantly white-hot, the ingots are seized by hydraulic cranes, raised from their moulds, and carried off to the rolling-mills. The ingots are in the form of parallelopipeds, very unlike the railway bars into which they are to be converted. These ingots are seized between a pair of rollers driven by very powerful engines; the rollers compress the ingot and elongate it; it is then passed again and again through the rollers, and gradually becomes a long bar. In the rollers are grooves, which are of the proper form to give shape to the bar; it is sent through these grooves, and finally, after passing through a series of them, it is a complete railway line. It is then, while still retaining a great deal of the original heat which it had as an ingot, carried to a saw-mill, which cuts off the ends, thus making the bar neatly finished, and of the proper length. We condense the following account of the rolling of iron from Fairbairn's work upon iron:—

"There are different kinds of rolling-mills used in the iron manufacture, and they vary considerably in their dimensions, according to the work they have to perform. The first through which puddled iron is passed are called the puddling rolls; there are others for roughing down, which vary from 4 feet to 5 feet long, and are about 18 inches in diameter; those for merchant bars, about 2 feet 6 inches to 3 feet long, and 18 inches in diameter, are in constant use. The boiler-plate and black sheet-iron rolls are generally of large dimensions; some of them, for large plates, are upwards of 6 feet long and 18 to 20 inches in diameter. These require a powerful engine, and the momentum of a large fly-wheel, to carry the plate through the rollers; and not unfrequently, when thin wide plates have to be rolled, the two combined prove unequal to the task, and the result is the plates cool and stick fast in the middle. The greatest care is necessary in rolling plates of this kind, as any neglect of the speed of the engine or the setting of the rolls results in the breakage of the latter, on the one hand, or bringing the former to a complete standstill on the other.

"The speed of the different kinds of rolling-mills varies according to the work they have to perform. Those for merchant bars make from 60 to 70 revolutions per minute, whilst those of large size, for boiler-plate, are reduced to 28 or 30; others, such as the finishing and guide rollers, run at from 120 to 400 revolutions per minute. In Staffordshire, where some of the finer kinds of iron are prepared for the manufacture of wire, the rollers are generally made of cast-steel, and run at a high velocity. Such is the ductility of this description of iron, that in passing through a succession of rollers it will have elongated to ten or fifteen times its original length, and when completely finished will have assumed the form of a strong wire, a quarter to three-eighths of an inch in diameter, and 40 to 50 feet in length.

"A high temperature is an indispensable condition of success in rolling. The experience of the workman enables him to judge from the appearance of the furnace when the pile is at a welding heat, so that when compressed in the rolls the particles will unite. Sometimes it is necessary to give a fine polish or skin to the iron as it leaves the rolls, but this can only be done when the iron cools down to a dark-red colour, and by the practised eye of an intelligent workman."

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By George Gladstone, F.C.S.

DISTRIBUTION OF THE MOST USEFUL MINERAL PRODUCTS—NATURE OF BEDS AND LODES—IMPORTANCE OF STUDY OF GEOLOGY.

To the inhabitants of the British Islands there is no industry that will compare in importance with that founded upon the substances which lie below the surface of the ground. Two articles—coal and iron—form the very groundwork of our national prosperity, but there are many others which are also worthy to be ranked as of first-class importance. Cornwall and Devonshire supply nearly all the tin ore raised in Europe. The slates of North Wales have a world-wide reputation. The salt-mines of Cheshire and Worcestershire enjoy advantages over their Continental rivals in respect of their proximity to shipping ports, which greatly add to their commercial value. In the succeeding papers, which purpose to include not merely the ores of the metals, but the other mineral substances which are made to contribute to man's comfort, it will become evident that these islands are, in proportion to their size, singularly rich in these articles.

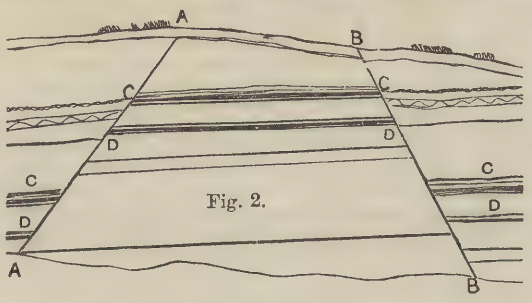


Fig. 2.

This might indeed be inferred from the fact that within the comparatively limited area of the United Kingdom almost all

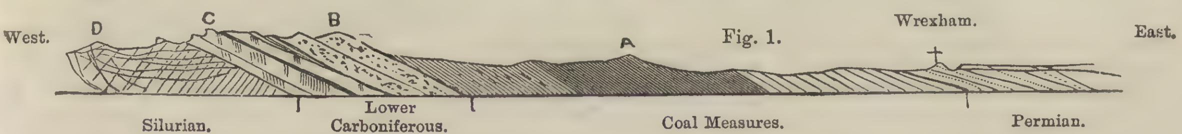


Fig. 1.

the important geological formations, from the newest tertiary to the oldest primary schists, are represented, and that in many places these have been upturned and pierced by eruptive rocks. The undulating or hilly surface, by which this country is distinguished from many others, is the effect of geologic disturbances which are highly beneficial to man. A level country is seldom rich in its mineral productions.

Let us take in order some of the principal groups of strata, commencing with the newest, and see what useful substances they contain.

Tertiaries	Brick clays, pipe-clay, septaria or cement stones, gypsum, coprolite, sand.
Cretaceous	Lime, brick clays, flints, fuller's earth.
Wealden	Sand for glass works; clays.
Oolites / Lias	Iron ores, alum shales, jet, cement stone, lime, clays, building stone.
Trias / Permian	Salt, gypsum, brick clays, building stone.
Carboniferous	Coal, limestone, fire-clay, oil shales, lime, sandstone, marbles, zinc, lead, silver, baryta.
Devonian	Tin, copper, sulphur ores, flag stones.
Silurian	Lime, lead, copper.
Cambrian	Slate, zinc, lead, copper.

In addition to these there are the eruptive rocks, such as granite and serpentine, which furnish excellent building and ornamental stones. Some particular kinds of the former, which readily decompose on exposure to the air, furnish kaoline, of which the finest china is made.

Now, if these various rocks were all to lie conformably one upon another, as in the foregoing list, the country would present the appearance of a plain, and the lower strata would be so far below the surface as to be practically unapproachable. The temperature of the earth increases at the rate of one degree Fahrenheit for about every fifty-five feet in depth; so that the increase of heat will infallibly prevent men from working below a certain depth; some of the tin mines in Cornwall are indeed carried almost to their extreme limit in this respect, the temperature being so high to render the mining operations very exhaustive.

The effect of the rise in temperature may be readily calculated. The first 100 feet from the surface are more or less subject to the changes of the seasons; but at about that point the temperature is uniform all the year round, and agrees with the mean temperature of the surface. Let us take that, therefore, at 50° Fahr. From that point downwards the increase is 1° for every 55 feet; so that at 1,650 feet from this point, or 1,750 feet from the surface, we shall have an addition to the temperature of 30°, making the temperature at that depth 80° Fahr. This measurement bears a very small proportion to the thickness of the sedimentary strata composing the crust of the earth, which, if they occurred in a complete series, would, it is estimated, extend to a depth of 14 miles, or 73,920 feet.

But this regularity scarcely ever happens in Nature; and there is no ground for the assertion that in any one particular spot all the known rocks are present, though of those which do occur the order of superposition is invariable. The Wealden and Trias, for instance, may be wanting in one place, the Cretaceous rocks in another, or they may be only very slightly developed; but the Cretaceous will never be found below the Oolite, or the Silurian above the Carboniferous. The various upheavals and subsidences which the crust of the earth has suffered, and which are represented by the hills and valleys, together with the subsequent denudation of the upturned edges, afford the opportunity of seeing at the surface in different parts of the country all the various strata, down to the very lowest of the series. Thus, for instance, in the annexed diagram (Fig. 1), which represents a section across the Denbighshire coal-field, about six miles in length, it will be seen that Wrexham stands upon the Permian rocks, that at A the coal beds crop out at the surface, while at B the millstone grit, at C the mountain limestone, and at D the Silurian rocks are exposed. At A, therefore, the miner can raise his coals at or near the surface; and even at Wrexham, by a calculation of the angle at which the coal measures dip to the eastward, he can estimate with tolerable accuracy the depth to which he would have to sink through

the Permian rocks and the upper coal measures, before reaching the same beds of coals as are found at A.

Such articles as coal, which always lie in seams or beds parallel to the plane of stratification, can thus be readily traced through considerable tracts of country with a greater or less degree of certainty. These calculations are liable, however, to be disturbed by faults, which are breaks in the continuity of the strata through some local disturbance, by which the seam may be suddenly raised above or depressed below its proper level. These are not unfrequent, and often cause great trouble and expense to the proprietors of the colliery. Fig. 2 will serve as an illustration of a double one. A A and B B are the lines of fault by which the continuity of the seams of coal, C C and D D, has been abruptly broken in two places. The displaced portion in this instance is raised above its proper level, and this would therefore be termed an *upcast fault.* A displacement in the opposite direction would be a *downcast.* Sometimes a fault occurs singly, whereas in other districts a succession of them, some up and some downcast, will be met with, breaking up the coal bed to such an extent as to prevent its being profitably worked. The surface ground often furnishes, as in the drawing, little indication of the faulty character of the rock below, the portion which has been thrown up being more liable to denudation than the surrounding country; and in like manner the depression in the case of a downcast fault is apt to get filled up.

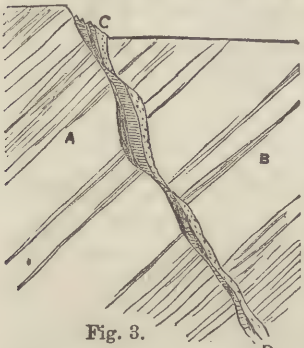


Fig. 3.

The ores of the metals, iron excepted, are not generally to be found in beds conformable to the stratification, but in what are termed *lodes* or *veins.* The former term is more commonly applied to the larger, and the latter to the smaller. A lode may be described as a long, narrow cleft extending through the rock from the surface downwards, in general at an angle not very far from the perpendicular, and usually taking a course somewhere near east and west. These are frequently intersected by others running nearly north and south, cutting the former, therefore, at about a right angle, which are termed *cross courses;* they are seldom so rich in mineral as the east and west lodes.

Just as in the faults which occur in the coal-fields, the lode is often accompanied by a change in the level of the rock through which it passes. Thus in the diagram (Fig. 3) the stratification on the side B will be seen to lie lower than that at A, and the fissure C D not being straight the lode is necessarily of very unequal breadth, the curves of the walls of the lode corresponding pretty closely, though thrown out of position. This is by no means an unusual occurrence, and it accounts for the great changes which frequently take place in the size of lodes in mines. The form of the fissure often greatly affects also the mineral contents. In mining language, the rock on the side A would be called the *standing wall,* and that at B the *hanging wall* of the lode.

The formation of the fissures in which the ore is deposited seems to be generally due to disturbances in the earth's crust, caused by the extrusion of some igneous rocks from below; the majority of such lodes being in the neighbourhood of masses of granite or other eruptive rocks, or where the sedimentary deposits have been much metamorphosed by subterranean heat. The processes in Nature's laboratory that have caused the clefts so made to be filled with mineral matter cannot be satisfactorily made out, as a similar result cannot be produced by artificial means. The igneous rocks themselves do not contain the metal, though the richest mines in England are those situated at the very junction of the granite with the clay slates of Cornwall.

Slate and building stone generally occur in much greater masses than either coal or the ores of the metals, and they are on that account rather quarried than mined, the workings being usually open to the light of day. Such slate, however, as is sufficiently good in quality for the purposes of trade does run in veins, and some of these lie at such an inclination, and penetrate so far into the bowels of the mountain, that open workings become impossible, and then the operations resemble much more those of the miner.

The value of slate is due to a peculiarity in certain of the older rocks—and especially the argillaceous beds of the Cambrian series—which is termed *cleavage.* In order to explain this novel feature let us take Fig. 4, which may be supposed to represent a gigantic block cut out of the mountain mass. The parallel lines A A, B B, C C, etc., will represent the stratification of the beds, a feature common to every sedimentary rock; but in addition to these we find here another regular series of divisions cutting them at a considerable angle, represented by the lines D D D, E E, etc., which represent the plane of cleavage. It is not merely at the intervals indicated in the drawing that the rock is thus affected, but the whole mass is liable at any point to split in a plane parallel to the cleavage, so that it can be divided into slabs of any desired thickness. It is remarkable, too, that the angle of cleavage remains constant through extensive districts, although the strata within the same range may be subject to great contortions. The cause of this change in the aggregation of the particles of which the rock is composed is very obscure, though it seems most probable that it may be due to heat or pressure, or both combined, especially as in many cases almost all traces of the original stratification have been lost.

In the course of the succeeding articles, these geological features, which so greatly affect the operations of the miner or quarryman, will have to be treated in more detail. But before closing these general remarks it may be well to point out more fully how important is a knowledge of the rudiments of geology, as well as mineralogy, to all those who seek for wealth below the surface of the ground. Were the authenticated instances, unfortunately, not too common, it would scarcely be believed what fortunes have been wasted in a fruitless search after minerals in places where it is impossible they could be found.

Bearing in mind the order of succession of the sedimentary rocks, we may illustrate this point by referring again to Fig. 1. The beds of coal in the Denbighshire coal-field lie in that part of the coal measures which is shaded the darkest, and they crop out at the surface at the part marked with the letter A. The dip is seen by the section to be towards the east. A comparatively shallow pit will cut the coal anywhere between A and Wrexham, though at the latter point the Permian rock would first have to be passed through. But if another adventurer were to sink a pit at any equal distance to the west of A—say at either B, C, or D, it is perfectly certain he would meet with no coal at all, however deep he might carry his explorations. He has begun at a point geologically below the coal, and every fathom he sinks is just so much further from the object of his search.

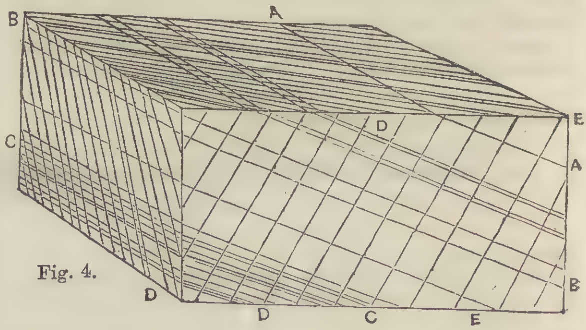


Fig. 4.

Some of the more recent strata contain thin layers of an impure coal, rarely in this country of any commercial value. These have often led to the sinking of pits, under the supposition that the true coal would be found, though a study of the dip of the neighbouring strata would show that the Carboniferous rocks must be so far below the surface as to be practically unapproachable. Thus there are borings for coal and deserted shafts to be found in many parts of the country; at Wincanton and Kingsthorp in the oolite, at Lyme Regis in the lias; at Tiverton in the millstone grit, and in Herefordshire in the mountain limestone; both rocks belonging to the Carboniferous system, but invariably below the coal, as seen at B and C in Fig. 1. At several spots in Wales these attempts have

been made in the Silurian, D; and at Bewdley a shaft has been sunk in the Devonian, which is also lower in the series.

Nor is it in respect of coal alone that such mistakes have occurred. In Cornwall some of the most valuable ores of copper used formerly to be thrown away as rubbish, the inferior ores only being recognised by the miner. In other parts of the country zinc-blende has been wrought, while the calamine, a very rich ore, has been entirely neglected. Iron pyrites has often been mistaken for gold. Thus, in one way or another, valuable produce has been lost, or money has been wasted in fruitless explorations.

In considering the mineral products, and the methods of treating them, more in detail in the subsequent articles, it will often become evident how greatly their value has increased through improvements in the mining and metallurgic arts, and that many have been added to the list of valuable minerals, the worth of which was unknown before.

OBJECT DRAWING.—I.

INTRODUCTION.

In presenting these lessons to the public, it is necessary to define their position in our series of Technical Lessons, and to set forth the purpose they are intended to accomplish.

The course, then, is designed to teach the elements of drawing as a useful language, to elucidate principles which are of such general use that by their application the student may be enabled to draw, not only the subject of the lesson, but numerous others of a similar character.

A further purpose of the lessons is to encourage drawing from the object instead of from copies. We are, of course, aware that beginners must necessarily copy drawings or prints; that copying is an indispensable branch of the study, as by its means practice is obtained in execution and design; and that from imitating the work of others, the student acquires experience in drawing and manipulation.

But these are only the means—not the result. When we teach our children common writing, and expect them to imitate the exact forms of the letters, it is never intended that the end and aim of their lessons shall be merely to copy other writing. We aim at giving them a knowledge of forms, by which words, the visible symbols of thoughts, may be expressed; and thus it will be clear that no system can be a true one which teaches copying only, without affording the necessary practice in drawing from the real subjects.

This course of object drawing must not, however, be supposed to compete with, or to take the place of, perspective proper. It is intended to be studied either before, or concurrently with, that subject, and it is believed that the system here laid down may interest students in the more severe course—that it may cause them to feel the want of accurate rules, in many instances where drawing by the eye must depend on judgment only; whilst the endless variety which object drawing affords must be a source of continuous pleasure to all.

To those who have already acquired some knowledge of Practical Perspective, the study of Object Drawing will be found exceedingly useful, since by its means the scientific methods previously acquired may be applied, and they will be able in a bold and rapid manner to give correct representations of things around them, in the same manner that a knowledge of the rules of grammar enables them to give a well-worded written description.

In order to make the course of lessons as complete in itself as possible, enough of the geometrical figures are given to enable students to construct the true forms with correctness; some of the elementary rules of perspective are also repeated in order to show their immediate application, and to explain how the appearance of objects becomes changed by their position in relation to the spectator. Perfection, then, in object drawing can only come from careful training in Geometry and Perspective; and any teaching which separates it from these, or implies that it is independent of them, is empirical. For the further working out of the rules thus briefly given the student is referred to the lessons on Perspective.

In order to enable teachers to carry out the system here laid down, a set of models has been specially arranged. They are designed not only to serve for separate studies, but may be combined and grouped in an almost endless manner, whilst their size is such as to render them useful in classes, enabling each student to make his observations as to form, light, and shade from his own point of view.*

Teachers are recommended to work out a simple perspective rendering of a model or group on the black-board; and in a subsequent lesson to set up the subject in a different position, to be drawn by the eye alone. This plan, since it shows the students the absolute importance of perspective, will increase the interest and enhance the value of such lessons.

The use of models may be further extended by the constant introduction of well-known objects, such as articles of household furniture, or domestic utensils, agricultural implements, and tools of every kind as subjects of study. Subsequently the pupils should be called upon to draw from memory, not only the subjects of recent lessons, but any they may have seen. The author has been enabled, in fact, by teaching the proper use of drawing, in even junior classes, to write a brief narrative on the black-board, and placing a dash under the leading nouns, to call on the pupils to draw them from memory—or, more properly, from imagination—and has found the plan so very successful that he advises teachers, with the greatest confidence, to adopt it, as not only is the knowledge possessed by the pupils drawn out, but habits of observation and study are cultivated and encouraged.

With the view of aiding students who may not have the use of sets of models, or who may not have the opportunity of making them of wood, patterns will be given from which the most important of the series may be made of cardboard. This in itself will be found good practice in the study of development.

Thus, then, we are enabled to add another contribution to our series of Technical lessons. Our earnest endeavour has been to make the instruction clear and simple, and in proportion to the success attained will be our gratification.

OF THE PRINCIPLES WHICH GUIDE DRAWING FROM OBJECTS.

Although we know that an object has in reality but one form, yet it will not seem the same to persons standing in different places, but its outline will vary with every movement of the beholder. This is called its "perspective appearance," and as this is subject to constant changes, it is clear that, in addition to knowing the exact form, we must study the causes of the alterations in appearance resulting from the different positions of the object, or from the relative place of the spectator.

It is not intended here to burden the mind of the student with a number of rules, such being fully elucidated in our "Lessons on Perspective;" and therefore only such as are absolutely necessary to enable the beginner to sketch from simple objects in a correct manner will be given.

We have, in our first lesson on Perspective, stated that "the moment we open our eyes a flood of light enters, and the rays which pass from the surfaces of every object are thus conveyed by the eye to the brain."

Since, then, we see objects by means of light, it will be clear that if the rays did not proceed from every part of such surfaces, we should see some portions and not others; and further, if the rays were not reflected in every direction, the object would be visible to *some*, but not to all the persons present.

Now it is evident that if a cube were placed in the middle of a room, and the students were seated around, *all* would see it; each might behold different sides, but every one would obtain *some* view of the object. Again, if students were located in a gallery formed after the fashion of a flight of steps, and a cube were suspended midway between the ceiling and the floor, those on the lower steps would see the bottom of the object, those on the middle steps the front only, whilst the spectators on the highest seats would see the top.

From this knowledge, then, which will be clear to all, we deduce the following principles:—

1. *Objects are seen by means of rays of light which proceed in straight lines, in every direction, and from every part of their visible surfaces.*

* "Ellis A. Davidson's Technical Drawing Models." Cassell, Petter, and Galpin.

2. *The view obtained of an object depends on the position of a spectator.*

If the eye be above the object, the top will be seen; if below, the bottom; whilst the left or right side will become visible according to circumstances.

The first consideration must be the height of the spectator in relation to the object. Let the student, then, ask himself, "Is my eye higher or lower than the object?" This will, of course, be at once evident. He should then consider, "If my eye *is* higher than the object, *how much* higher is it?" and this will lead us to the following principle:—

The horizontal line represents the level of the eye of the spectator in relation to the object.

Therefore, if an object be placed above the horizontal line, we see the bottom, and if above, the top of it; and the view will vary according to the height of the eye.

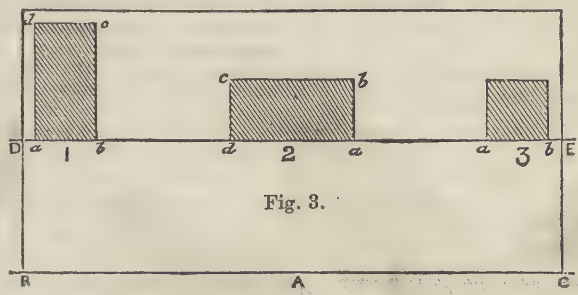


Fig. 3.

But the knowledge as to height will not in itself be sufficient; we must be clear as to whether we see the left or right side; and this brings us to the consideration of the point of sight.

The point of sight, or centre of vision, is the point in the horizontal line which is directly opposite to the eye of the spectator.

We now proceed to show the use of these principles, at the same time urging the student not to be content with the illustrations here given, but to observe their application to all the objects by which he is surrounded.

Let the rectangle A B C D (Fig. 1) represent the general form of the front of a case of shelves, and let E F be the horizontal line. It will then be clear that the object to be represented is twice as high as the eye of the spectator, since the horizontal is drawn across the middle of the height.

The spectator is supposed to be situated on the right side of the object, opposite to PS, which indicates the *point of sight.* It will be evident, that whilst the horizontal edges of the case, A D and B C, which form the top and bottom of the front, and also those corresponding with them at the back, are *parallel* to the picture, the lines of the other edges are at right angles to A D and B C, and consequently at right angles also to the picture. To render these correctly, it is required to understand the following rule:—

All lines which in the object are at right angles to the plane of the picture—that is, such as run directly from the spectator to the distance—must be drawn to the point of sight.

This rule will at once give the direction in which the lines C G and D H are to be drawn; and it will be evident that the narrow ends of the shelves, I J, K L, M N, O P, being in the object parallel to the narrow end of the top and bottom, will converge to the point of sight.

Now, on referring to the illustration, it will be seen that whilst the lines representing the ends of the shelves which are below the horizontal line—viz., M N and O P—are drawn upwards to the point of sight, those which are above (I J, K L) are drawn downwards; thus we see the upper surface of those below, and the underneath surface of those above; and of the shelf which is on a level with the horizontal line—viz., Q R—we see the edge only, neither the upper nor the under side being visible.

Fig. 2 shows the same object when placed on the right side of the spectator, the front of the case being at right angles to the plane of the picture.

Let us now proceed to the practical application of the principles thus far laid down. We will, in the first case, suppose you sitting at a table, the edge of which is parallel to your chest. Let the figure here drawn (Fig. 3) represent the top of the table, and let your position be at A. Now on the opposite side of the table are three equal blocks which are square at their ends, and doubly as long as they are thick.

The artisans to whom these lessons are principally addressed will have no difficulty in providing themselves with three such blocks, which may be of wood, stone, or plaster of Paris, etc. A very convenient size is four inches square by eight inches long; but, of course, the principles about to be explained would apply to objects of any size or proportions: for drawing purposes, however, the blocks should not be smaller than these.

Place a model (1, in Fig. 3) on one of its long faces, with its square end parallel to the edge of the table, B C. All its long edges, as *a d* and *b c*, will then recede at right angles to the square end which stands on *a b*. Place another block (2) so that whilst resting upon one of its long sides, another is vertical, and parallel to B C; and, finally, place the third block (3) on its end, so that the long face in the front, and the other at the back, may be *upright*, and parallel to B C. You will, of course, remember that the rectangles 1, 2, 3 in Fig. 3 are called the *plans* of the objects.

We will in our next lesson attempt, guided by the above figure, to draw these models, as they appear to you from the position in which you are placed.

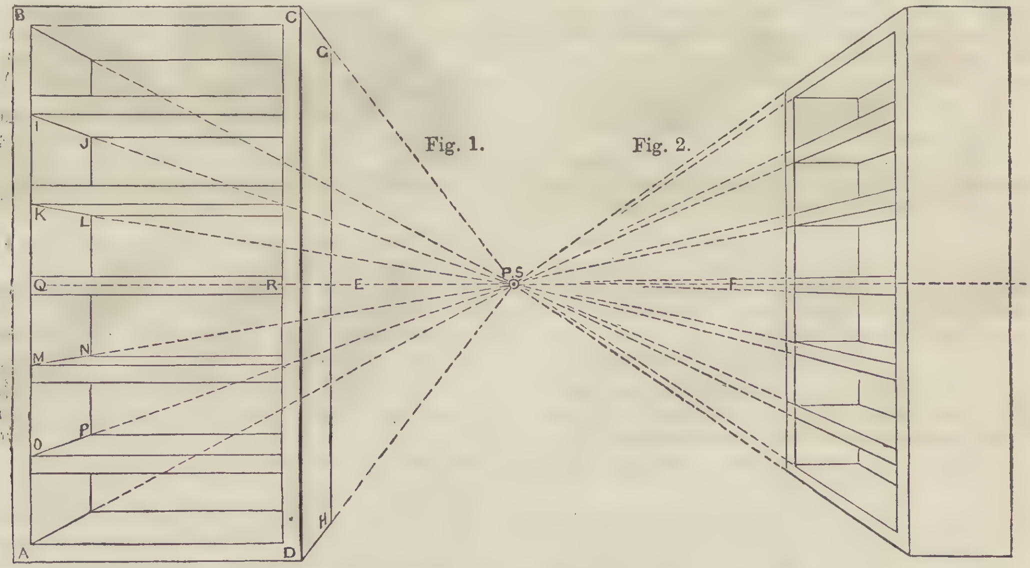


Fig. 1.

Fig. 2.

BUILDING CONSTRUCTION.—XIV.

JOINTS IN TIMBER (*continued*).

Fig. 125 shows another method by which timbers are "notched" on to each other. This is a very good system, for the upper holds as it were by a hook, which acts against a shoulder in the lower. The upper is thus prevented being drawn inward by weight placed upon it, and the lower is strengthened against any pressure which might tend to force it outward.

Fig. 126 is a joint of a similar character, a dovetail being employed in this case, which in Fig. 127 is further secured by an additional shoulder.

Figs. 128 and 129 are methods by which the ends of timbers are firmly attached to beams or wall-plates on which they rest.

THE CONSTRUCTION OF FLOORS.

The assemblage of timbers by which floors are supported is called the "naked flooring," and is of three sorts—single, double, and framed.

Single Flooring consists of one row or tier of joists, bearing from one wall or partition to another without any additional support. On these rests the flooring boards, and to their lower edge is attached the ceiling of the room below (if there be any), either by means of laths or ceiling-joists.* These floor-joists rest upon a wall-plate built into the wall; the brickwork of the wall should not quite touch the end of the joist, but should leave a small space all around the end; this prevents any damp in the wall from spreading into the timber, and allows of a certain play of air around it. In better work, however, the ends of the joists

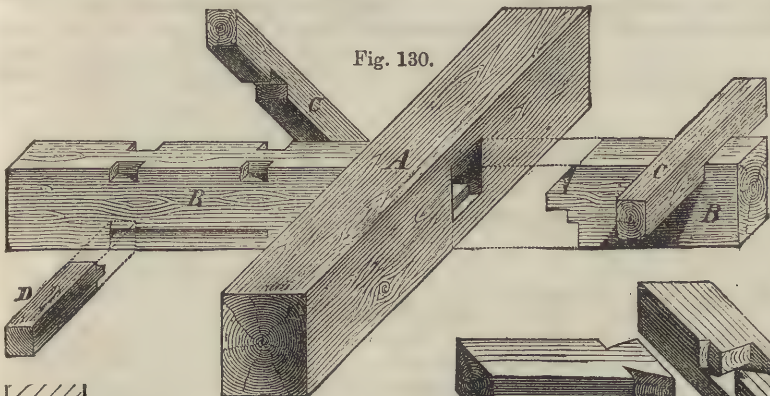


Fig. 130.

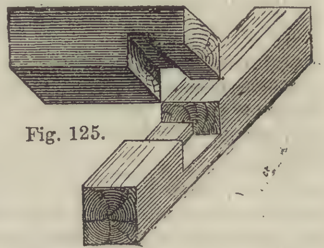


Fig. 125.

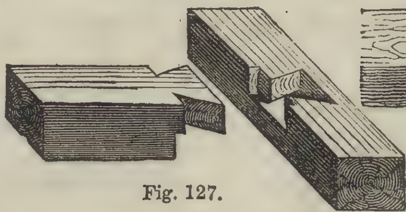


Fig. 127.

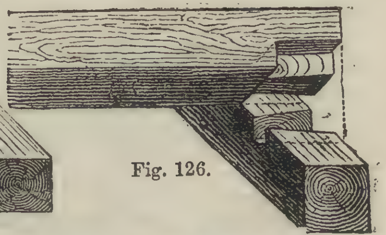


Fig. 126.

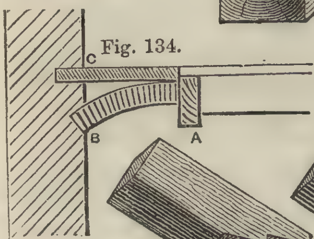


Fig. 134.

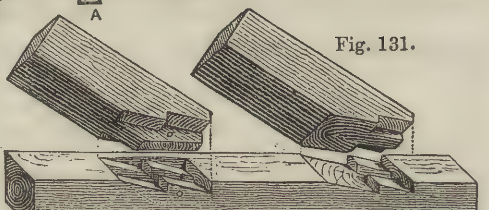


Fig. 131.

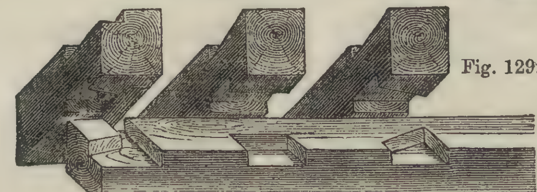


Fig. 129.

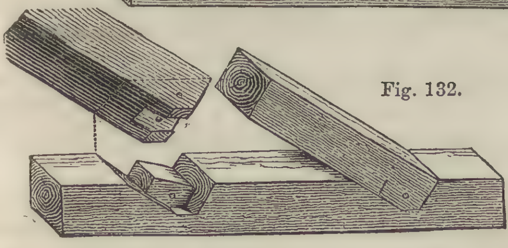


Fig. 132.

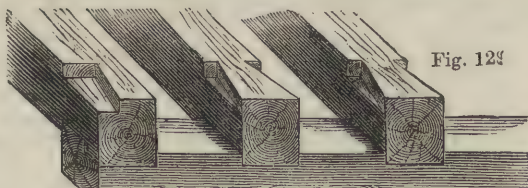


Fig. 12

The upper surfaces are shown as cut for the reception of an upper timber to further bind them together.

Fig. 130 is the Continental mode of constructing framed flooring, and is here introduced in order to compare it with our system, which is explained and illustrated on the following page. Here A is the girder, B B the bridging-joists, and C the floor-joists.

In this example it will be seen that the ceiling-joist, D, is not notched on the under surface of the binders, but is inserted by a tenon and groove. The groove or slot being made longer than required, the ceiling-joist is placed slantingly across between two binders, its ends being in the opposite ends of the grooves; and by being struck sharply and sufficiently with the mallet it is forced into its proper direction at right angles to the binding-joists.

Figs. 131 and 132 show four different kinds of oblique mortises. The principles on which such joints are worked have already been described.

are gathered by wooden end-ties and iron tie-rods. These are drawn up by nuts, the joists being meanwhile shored up in the middle, so that when this support is removed the joists may be stiffly braced. Another plan is to rest the wall-plate on projecting corbels, by which means the ends of the joists do not enter the walls at all; and thus any fracture, such as might arise from shaking, crowding, dancing, etc., is avoided. The wall-plates for basement-floors are best supported on short piers carried up from the footings. Joists in single floors should never be less than two inches, nor even as small as that where it can be avoided; and they should not be farther apart than twelve inches from centre to centre. They may be strengthened by increasing their depth (which should not be less than nine inches), and may be prevented from twisting by putting a herring-bone truss between them (Fig. 133). This consists of

* Ceiling-joists are timbers of small scantling notched on to the lower edges of the joists, and to these the laths are attached.

pieces of batten an inch and a half thick and three inches wide, or thereabouts, placed diagonally between the joists, to which they are nailed in the diagonal form shown. They should be ranged in a right line, so that none of their strength may be lost, and these ranges should be repeated at intervals not exceeding five or six feet. This strutting should be done to single flooring under any circumstances, as it adds materially to its firmness, and indeed to its strength, by making the joists transmit any stress or pressure from one to another.

The strength of single flooring is materially affected by the necessity which constantly occurs in practice of "trimming" around fire-places and vacuities. Trimming is the mode of supporting the end of a joist by tenoning it into a piece of timber running at right angles to it, instead of running it on into the wall which supports the ends of the other joists; and by this means the placing of timber under hearth-stones is avoided.

Fig. 134 shows the sectional elevation of this arrangement. The cross-piece A, called the *trimming-joist*, is united at both ends to the joists running the entire length or breadth of the floor by means of strong tenons; and these joists, having to bear the weight of several which run into the trimming-joist, should be made stouter than the others; and a brick arch, B, called the *trimming-arch*, should be thrown across from the wall to the trimming-joist, on which the hearth-stone C may rest.

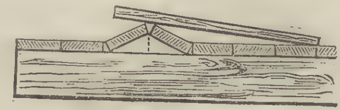


Fig. 140.

Fig. 135 shows the mode of preventing sound passing through floors. Narrow fillets, *a a*, are

Fig. 137.

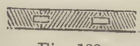
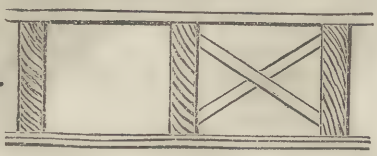


Fig. 138.

Fig. 139.

Fig. 133.



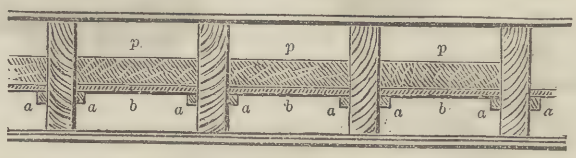


Fig. 135.

nailed to the floor-joists, and on these boards called sound-boards, *b b b*, are fixed; "pugging," which is a coarse sort of mortar, etc., is then filled in as at *p*.

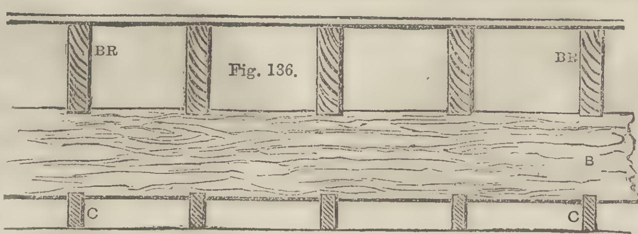


Fig. 136.

Double Flooring, a section of which is shown in Fig. 136, consists of three distinct series of timbers—viz., the binding, B, bridging (or floor), BR, and ceiling-joists, C. In this system the binders are the real supports of the floor; they run from wall to wall, and carry the bridging-joists above, and the ceiling-joists, C, below. Binders need not be less and should not be more than six feet apart. The bridging-joists are notched down on to the binders in the manner shown in Fig. 112; but in notching the ceiling-joists to the lower edge of the binder the whole notch must be taken out of the ceiling-joist, as the lower part of the binder must not in any way be wounded or weakened. The details, as already given in relation to single floors are, of course, equally applicable to the system here described.

Framed-Flooring, a section of which has already been shown (Fig. 117), is composed of girders (G), bridging joists (B), floor-joists, and ceiling-joists.

Girders are large beams, either formed of one piece or built up, according to the length required and the size and strength of which timber can be procured. They are intended for longer bearings than binders, and may be strengthened by trussing, as already shown in Figs. 100, 101, 103, and 104. To be efficient, the height of the truss should always be greater than the girder itself, and the strength is increased by extending that height as the space or bearing increases.

Binders are made dependent upon the girders by means of double tusk tenons. This mode of joining has already been illustrated in Fig. 117.

It must be observed that the binders should not be mortised into the girders opposite to each other, since the girder would be unduly weakened by being mortised on both sides at the same place.

The floor-boards are nailed either at one or both edges. The longitudinal joints, or those in the direction of the fibres, are either square (Fig. 137), ploughed and tongued (Fig. 138), or rebated and lapped over each other (Fig. 139).

Ploughed and tongued and rebated joints may be used where the apartment is required to be air-tight, the heading joints being either square or ploughed and tongued. Sometimes, instead of a tongue extending all the length, separate pins are used, called dowels, which run into holes in the next board. In square longitudinal-jointed floors it is necessary to nail the boards on both edges; but where the boards are dowelled, ploughed and tongued, or rebated, one edge only need be nailed, as the tongue or lapping is sufficient to keep the other down.

In the most common kinds of flooring the boards are folded together in the following manner:—Supposing one board already laid and fastened, a fourth, fifth, sixth, or other board is also laid and fastened, at such a distance as to admit of two, three, four, five, or more boards between the two, but which can only be inserted by force, as the breadth of the opening must be barely that of the aggregate width of the boards, in order that the joints may be close when they are all brought down to their places. For this purpose, a plank (Fig. 140) may be thrown across the separate boards laid, which may be forced down by two or more men jumping upon it. This done, all the intermediate boards may be nailed down, and the operation is to be repeated until the whole is complete. In this system, which is called "folded flooring," less than four boards are seldom laid together. No attention is paid to the heading joints, and sometimes three or four such meet in one continued line.

In dowelled floors, the distances to which the dowels (or projecting pins) are set are from six to eight inches, generally one over each joist and one over each interspace. No heading joint of two boards ought to be so disposed as to meet the heading joints of two other boards, and thereby form a straight line equal to the breadth of two boards.

Laying down the floor-boards is usually classed under joinery, but it is found more convenient to treat of this branch in the present section, in connection with the construction of the floors themselves.

AGRICULTURAL CHEMISTRY.—VII.

BY CHARLES A. CAMERON, PH.D., M.D.,

Professor of Hygiene in the Royal College of Surgeons, Ireland, etc.

CHAP. VII.—ON MANURING AND NATURAL MANURES.

As stated in a previous chapter, it is practically impossible to reduce, by any system of tillage, fertile land into a state of barrenness. The food of plants is so abundant in soil and air, that it is beyond the power of man to diminish its amount, except to a trifling extent. In order, however, to maintain the soil in its highest degree of productiveness, the elements extracted from it in the form of crops must be in great part restored in the form of manure. A naturally good soil, carefully tilled but unmanured, will yield average fair crops for many years; but good land, which is both properly tilled and abundantly supplied with manure, alone yields maximum returns for the labour and materials expended upon it.

The laborious and long-continued experiments of Messrs. Lawes and Gilbert have given results which prove that in wheat land of average quality the application of tricalcic or monocalcic phosphate (bone phosphate and soluble phosphate of lime) frequently produces little, if any, effect upon the growth of wheat. That plant possesses an extensive root-absorbing surface, and throws out its rootlets to a considerable distance from its stem. It also, when sown in autumn, is enabled to collect mineral matter from the soil during the winter and early spring. On the other hand, barley, which is sown in the spring, has less time to draw upon the resources of the soil, and therefore it is far more likely to be benefited by the direct application of manures containing phosphates. Both wheat and barley, and the cereals generally, appear to be much more influenced in their growth by the application of ammoniacal manures, than by that of phosphatic or alkaline compounds. Potassic silicate, believed at one time to be an excellent application to the cereals, on account of the large amount of silica or flint they contain, has been proved to have no effect whatever in strengthening the stems of those plants. The cereals, if well supplied with nitrogenous fertilisers, may be grown more frequently in the rotation than is usually the case; indeed, they may be produced year after year without the interposition of other crops, but for the difficulty of keeping the fields free from weeds.

Most leguminous plants—vetches, clovers, etc.—do not seem to be much benefited, as a general rule, by the application of ammoniacal manures. Potassium salts are, on the other hand, almost certain to stimulate the growth of these crops. The large leaf-surface of all the members of the Leguminosæ enables them to extract abundance of combined nitrogen from the atmosphere, and hence the amount of ammonia in the soil often increases, instead of decreasing, during the growth of clovers and allied plants. In the rotation wheat should always succeed clover, because the latter crop will provide the former with nitrogenous matter, which is so indispensable to the luxuriant development of the cereals.

Bulky organic manures (farm-yard manures, decomposing straw, and similar matters), and the manufactured fertiliser known under the term superphosphate of lime, produce marked effects upon root-crops—turnips, mangolds, etc. The natural grasses grow luxuriantly if supplied with nitrogenous manures, and they are not to any important extent dependent upon the use of bulky natural manures. Sodic nitrate generally produces a powerful stimulative action upon the grasses. Potatoes appear to be far more benefited by the application of potassium salts (kainit, "muriate of potash," and kelp) than by that of ammoniacal salts. In many cases the nitrogen of sodic nitrate (nitrate of soda) is more effective when applied to potatoes than the nitrogen of ammonia.

The manures used in this country are very numerous, and are derived from the three kingdoms of Nature. We cannot refer to all that are in use, for our space will only permit us to describe the more important ones.

Farm-yard manure is the staple fertiliser of the British farmer, and in general all others are more or less supplemental. It is composed of the liquid and solid excreta of various animals commingled with straw; but it occasionally includes ashes, turf, mould, leaves, and all kinds of house rubbish of an organic origin. Its composition varies very much, and depends to a great extent upon the care with which it is preserved. Some years ago we made four analyses of farm-yard manures, and the following were the results at which we arrived:—

	No. 1.	No. 2.	No. 3.	No. 4.
Water	73·22	64·12	65·22	69·14
Organic matter	21·17	29·28	28·14	24·21
Containing ammonia free, in combination with acids, and latent	(0·150)	(0·784)	(0·550)	(0·612)
Tricalcic phosphate	1·73	1·75	1·88	1·64
Alkaline salts	1·30	1·09	1·86	0·94
Calcium and magnesian compounds	1·38	1·82	1·24	2·12
Silica, oxide of iron, etc.	1·20	1·94	1·66	1·95
	100·00	100·00	100·00	100·00

No. 1 was composed chiefly of the solid excretion of the horse and cow, the liquid excreta having been allowed to drain away, and most of the soluble portion of the manure having been washed out by rain. Nos. 2 and 3 were composed of the solid and liquid excrement of horses and cows, and as they had been properly preserved, the amount of ammonia was high. No. 4 contained some pig manure in addition to that derived from horses and oxen. It was carefully preserved under cover, and its proportion of ammonia was also large.

The composition of the excreta of the farm animals is shown in the following tables:—

COMPOSITION OF THE SOLID EXCRETA OF THE ANIMALS OF THE FARM.

1,000 parts contain—	Horse.	Cow.	Sheep.	Pig.
Water	750	850	640	700
Solid matters	220	150	360	220
Containing nitrogen equal to ammonia	6	3·5	6	7
" phosphoric acid equal to phosphate of lime	8	6	5	5
Alkaline salts	3·5	2·20	3	5·5

COMPOSITION (PER 1,000 PARTS) OF THE LIQUID EXCRETA OF THE FARM ANIMALS.

	Horse.	Cow.	Sheep.	Pig.
Water	900	920	900	975
Solid matter	100	80	100	25
Containing nitrogen equal to ammonia	14	9	14	3
" alkaline salts	14	16	10	[illegible]

The amount of phosphoric acid is very small in the liquid excrements, varying from a trace to about 0·1 per cent. in the case of horses, oxen, and sheep. In pigs' liquid excreta it amounts to from 0·75 to 1·5 per 1,000 parts.

The composition of the excreta of the farm animals is very variable, and is greatly influenced by the nature of the animal's food, and other conditions. Two specimens of the liquid excretion of the sheep which I analysed (see *Gardeners' Chronicle* for March, 1860) gave the following very different results:—

	No. 1.	No. 2.
Specific gravity	1045	1014
Water	87·16	95·88
Urea and undetermined organic matter	9·38	2·95
Yielding by combustion with soda—lime, ammonia	(3·20)	(0·85)
Inorganic matters, chiefly alkaline salts	3·46	1·17
	100·00	100·00

No. 1 had been obtained from a sheep "highly fed," and No. 2 from a sheep poorly fed.

The solid manure of the horse is very valuable. It decomposes rapidly in the soil, which becomes thereby sensibly warm. It is, therefore, properly termed by farmers a *hot manure*. On the other hand, cow manure is cold, because it long resists decomposition. Owing to the coherent, pasty character of this manure, it is difficult to distribute it equably throughout the soil. Sheep manure is nearly as valuable as that furnished by the horse, but it does not decompose so readily. The manure of the pig appears to vary more in composition, probably owing to the omnivorous nature of the porcine species, than that of the other three animals above referred to. It is a *cold* manure, and is pasty and tenacious. Its composition indicates that it is capable of greatly enriching the soil, and on the Continent it is held in great repute amongst the farmers. For my part, I should prefer horse manure to it.

The best position for the manure heap is on level ground, for if placed on a sloping site the drainage from it soon diminishes its value, and if it be deposited in a hollow its base soon becomes rain-water. A paved site is desirable, as soft soil absorbs valuable soluble matters from the manure. The larger the heap is the less it loses by the influence of sun, air, and rain. The common practice of allowing the manure to remain in small heaps is most wasteful. When the heap is large and compact, very little loss is sustained by evaporation; but heavy rains dissolve and carry away some of the soluble matters. This loss may be averted by surrounding the base of the manure heap with earth or peat mould, and when the latter becomes saturated with the fertilising matters it may be thrown up on the top of the heap. A stratum of fine earth or peat-mould a foot in depth constitutes an excellent foundation for the manure heap. Farm-yard manure may be spread over the field a long time before it is actually required. Under such circumstances, it loses little, if any, of its fertilising ingredients, as the soil absorbs and retains them.

The treatment of liquid manure is a point of considerable importance; but we shall postpone its consideration until we come to treat upon the subject of liquid sewage.

WEAPONS OF WAR.—VIII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

GREAT GUNS AND THEIR PROJECTILES (*continued*).

In our last paper we treated of smooth-bore ordnance, and of the various natures of shot which are used with the same—solid, steel, chilled, hollow, case, and grape shot.

We pass now to the consideration of the second group of projectiles, Shells. There are two great classes of shell—Common shell and Shrapnel shell. The common shell, for smooth-bore guns, is a hollow sphere of cast-iron filled with powder and fitted with a fuse, which is so arranged as to explode the shell either at a particular time after it has left the gun, or when it strikes against some hard object. A shell is, in fact, a small mine which is transferred by the power of a gun to any spot where its effect may be required to be produced: it has been called a "flying mine," and the effect, it will be observed, is really independent of the gun. That is to say, a common shell, if deposited on a particular spot by hand and then fired, would cause almost as much destruction as if it had been shot on to that spot from a gun. This, at least, is the primary application of a common shell, and it is one which it is important to appreciate, because it constitutes the leading distinction between shells of the common and shells of the Shrapnel class. It follows from the above, that a common shell acting as a mine is especially destructive against the *matériel* of an enemy. It destroys his parapets; it blows down his walls and defences; it carries destruction into his towns and villages; but, beyond and above all, it is especially terrible when it can be introduced into his ships. Shells are more dreaded by the sailor than any other projectile, and naturally so; for the bursting of a shell in the confined space between the decks of a vessel is destructive alike to men and material; it blows the former to pieces, it destroys and sets fire to the latter, and it causes confusion and terror by its noise and smoke. The following passage, which gives a "realised epitome" of shell effects on board ship, has been often quoted, but may be here fitly reproduced. It is an account of the fight between the iron-clad *Merrimac* and the wooden ship *Congress*:—"The first shell that burst within the *Congress* killed every man at the nearest gun; another and another burst among the crew, and the ship was soon a slaughter-house. Operations were now out of question. The wounded were in crowds horribly cut up. The ship, too, was on fire; the shells had kindled her wood-work in various places. Nearly all the guns were dismounted, the bulkheads blown to pieces, handspikes and rammers shivered, and the powder-boys all killed. Everything was in fragments, black or red, burnt or bloody. This horrible scene lasted about an hour and a half, and then she struck." This vivid description was given by an eye-witness.

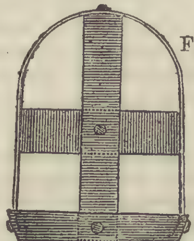


Fig. 3.

Fig. 4.

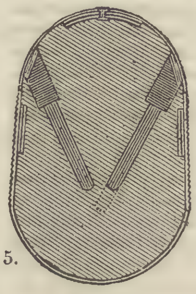


Fig. 5.

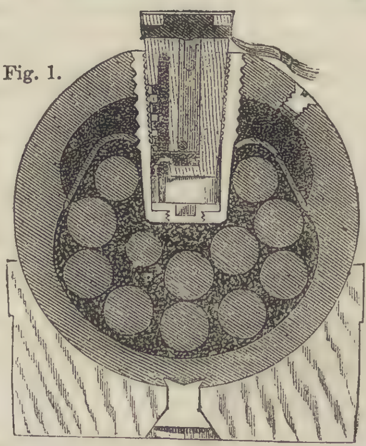


Fig. 1.

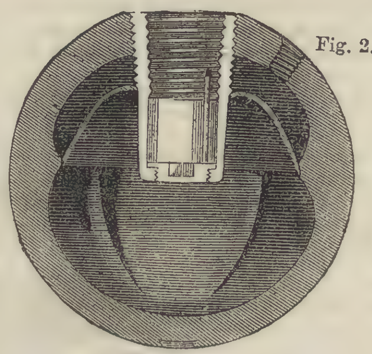


Fig. 2.

Fig. 1.—SECTION OF DIAPHRAGM SHRAPNEL SHELL, WITH FUSE COMPLETE. Fig. 2.—SECTION OF DIAPHRAGM SHRAPNEL SHELL, WITHOUT BULLETS. Fig. 3.—SKELETON FRAME OF GROUND LIGHT BALL. Fig. 4.—GROUND LIGHT BALL COMPLETE. Fig. 5.—SECTION OF GROUND LIGHT BALL.

A secondary use of the common shell is to act much as the Shrapnel acts—viz., to burst somewhat in advance of the object fired at, when the fragments, continuing their flight, spread out and act in the same way as a charge of case or grape. But this is to be understood as distinctly a secondary use of common shells; for in this case the large bursting charge which the shell contains is in a great measure thrown away. Indeed, it may be said to detract from the efficiency of the projectile, because it blows a number of the fragments sideways, and arrests the progress of others.

But this brings us to that class of shell which is specially intended to act in this way—Shrapnel shell. The first idea of these important projectiles was conceived by General Shrapnel, of the Royal Artillery, at the siege of Gibraltar, in 1781. The guns were firing at a range beyond that of case or grape, and some effective *direct* fire was made with common shell fired from 24-four pounders with large charges of powder. The projectile's velocity was very great, and the loss to the enemy was considerable. It then occurred to General Shrapnel that if he were to fill these shells with musket and carbine balls, reducing the bursting charge to a *minimum*, consistent with the opening of the shell, and increasing the firing charge to a *maximum*, he would be able to produce a still more destructive fire. In this change we note the distinctive difference, which cannot be too clearly appreciated, between common and Shrapnel shell—viz., the difference, that while the former depends upon the explosive effect of its own charge, the latter depends upon or derives its effect from the charge of the gun. A high velocity is not necessary in the first case; it is essential in the second. A large bursting charge is essential in the first case; it is not only not essential, but absolutely prejudicial in the second. The original Shrapnel shell, as designed by General Shrapnel, was, in fact, a thin common shell filled with bullets instead of powder, and having only so much powder in among the balls as would suffice to open the shell. The object of making the shell as thin as possible was, first, that it might contain as many balls as possible; secondly, that a very small bursting charge might open it. These projectiles were first introduced about the year 1803, and were used at the battle of Vimiera in 1808, and at other actions during the Peninsular war, with an effect to which the French, against whom they were fired, bear ample though unwilling testimony.

The action of the shell is as follows:—It leaves the gun like any other spherical projectile, travelling to the point at which the time-fuse has been set to explode it—which should be a short distance in front of the object aimed at. When it arrives at this point, if the action of the fuse be satisfactory, the shell will be opened, and the bullets and fragments will "continue their forward course with a communicated velocity equal to that of the shell at the moment of fracture, and describing, as

they slightly disperse, 'a curved cone, the apex of which is at the point of explosion.'" The Shrapnel shell thus acts as case or grape at distances beyond those at which case and grape can be effectively employed. The Shrapnel shell has practically the effect of carrying forward the muzzle of the gun to within such a distance of the enemy as will enable a case-fire to be delivered. Actually the muzzle of the gun is, of course, not advanced; but practically this is what happens, for the breaking up of the projectile, which with case occurs at the muzzle, is postponed until the projectile arrives within a short distance of the enemy. Indeed, when Shrapnel shell were first introduced, they were called by a name which exactly describes them—"spherical case shot." The present name was not adopted until many years afterwards, as a compliment to the inventor. Since the first introduction of Shrapnel shell, some important improvements and modifications have been adopted. It was found that the shells sometimes were broken up by the shock of discharge, due to the friction of the powder between the balls. To obviate this it was necessary to separate the powder from the balls, and this was done by introducing into the existing store of Shrapnel a tin cylinder, which occupied the centre of the shell, and contained the bursting charge. These shells were known as "improved Shrapnel," and they have only recently disappeared from the service. When new shells had to be made, General (then Captain) Boxer, R.A., proposed a different arrangement. He proposed to separate the bursting charge from the bullets by enclosing it in a small chamber formed on one side of the shell, by the insertion of a wrought-iron plate or "diaphragm." The accompanying drawings (Figs. 1 and 2) show the construction of the "diaphragm Shrapnel shell."

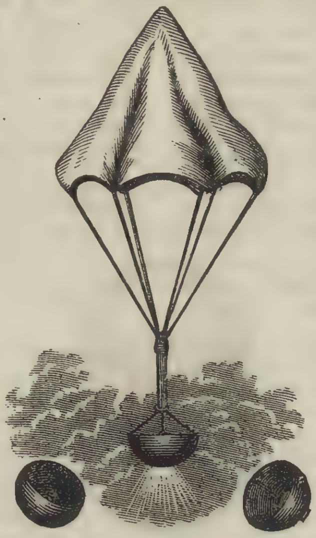


Fig. 6.—PARACHUTE IN ACTION.

The advantage of placing the bursting charge at one side, instead of in the centre, was that it avoided the excessive dispersion of the balls at the moment of rupture. But in order to ensure the proper opening of the shell, it was necessary to provide it with internal grooves, or "lines of least resistance," down which the powder would act. The powder is introduced into the chamber through a small loading-hole, and the fuse communicates with the powder in this chamber through a small fire-hole in the brass socket. To prevent the bullets from conglomerating under the shock of discharge, they are made of hardened lead, and have coal-dust shaken in between them. Such is the diaphragm Shrapnel shell for smooth-bore guns. We shall see hereafter how General Boxer has successfully applied the principles of this construction to the Shrapnel shell for rifled ordnance.

It will be observed that the shell in our drawing is fitted with a wood bottom, riveted on. All shells are fitted with one of these bottoms, or "sabôts." They serve the double purpose of presenting the right side of the shell—*i.e.*, the side away from the fuse—to the charge, and slightly diminishing "windage" (the space between the shell and bore), and thus reducing the escape of gas and the tendency of the projectiles to *ricochet* along the bore. With bronze guns, it was necessary to provide the shot, as well as the shell, with these bottoms, because otherwise a bounding movement of the shot became established, to the speedy destruction of the gun, and to the almost immediate destruction of all accuracy of fire. The method of attachment adopted for these bottoms—an expanding copper rivet—is simple and ingenious, and a great improvement on the plan formerly adopted—namely, "strapping" on the bottom with tin "straps."

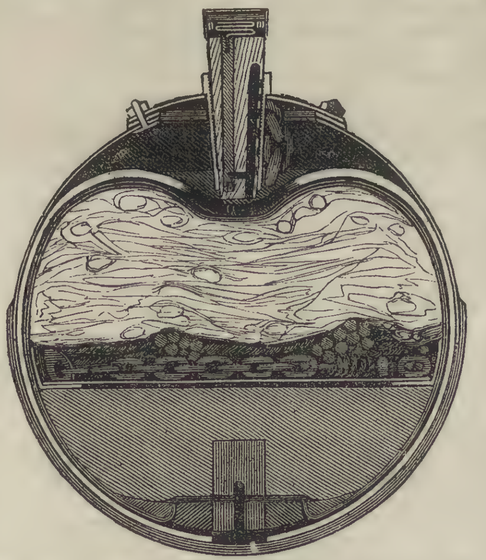


Fig. 7.—SECTION OF PARACHUTE LIGHT BALL, WITH FUSE.

We have now treated of shot and shell. There remains a third class of projectiles to speak of—*incendiary projectiles.* Of these there are six—viz., red-hot shot, Martin's shell, ground light balls, parachute light balls, and smoke balls.

Red-hot shot are merely ordinary cast-iron shot heated to a "wafer" red heat and fired, with reduced charges, against wooden shipping or any combustible material. It is necessary to fire them with reduced charges, because the expansion of the shot, by reducing the windage, increases the strain upon the gun, and because red-hot shot are required to lodge in the object fired at, and not to pass through it. These projectiles were used with great effect, and on a large scale, at the siege of Gibraltar.

Martin's shells have, in a great measure, replaced red-hot shot; although both descriptions of projectiles have lost their original value, in consequence of the substitution of armour-plated for wooden vessels. Martin's shell, so called after its inventor, a civilian, consists of a thin spherical cast-iron shell, with an interior lining of loam; shortly before use the shell is filled with molten iron. In order to ensure the breaking-up of the shell on striking an object, the sides are made thinner than the top and bottom. The loam lining, being a good non-conductor, serves the double purpose of keeping the iron in the interior hot and the external shell cool for a longer time than would be possible if there were no such lining. The shell is intended to be fired against an inflammable object—such as a wooden ship. The shock of concussion breaks the shell, and the molten contents are scattered about, setting fire to everything combustible upon which they may fall. These shells were considered by the committee which introduced them to possess greater incendiary power than red-hot shot. On the other hand, there is a certain amount of trouble and inconvenience involved in the preparation of the liquid iron. But when these difficulties are surmounted, and when the shell are used under favourable circumstances, they have been proved to be very formidable instruments of destruction.

Carcasses are thick iron shells, filled with a combustible composition, and having three holes for this composition to burn out of. The composition consists of a mixture of saltpetre, sulphur, rosin, sulphide of antimony, turpentine, and tallow. It burns with great violence for from three to twelve minutes, according to the size of the carcass, which varies from the 12-pounder to the 13-inch. Carcasses are thrown into an enemy's works, to set fire to his houses, stores, etc. etc. The composition becomes ignited at each vent by the flash of discharge, and continues burning after the carcass has fallen until it is expended. So violently does the composition burn, that it is almost impossible to extinguish it. It will even burn under water. The best mode of dealing with a carcass is to endeavour to roll it away from all inflammable material, and to smother it with earth.

The ground light ball (Figs. 3, 4, 5) is another projectile of this class. It is, however, useful rather for illuminating than for incendiary purposes. It consists of an oblong skeleton iron frame, covered with stout canvas and filled with an inflammable composition, consisting of saltpetre, sulphur, rosin, and linseed oil. The projectile has four or five vents, according to its size, from which the composition burns, for from nine to sixteen minutes,

according to the size. These ground light balls are thrown from mortars at night into an enemy's work, to discover his working parties; and they are also serviceable, in the absence of carcasses, as incendiary projectiles. They are, however, open to some serious objections. In the first place, an oblong projectile is not suitable for firing out of a smooth-bore gun; neither range nor accuracy can be obtained with it. Again, if they fall short of the object, their smoke makes a sort of screen. If they fall into a ditch or on to muddy ground they are smothered; and if they do fall in the right place, they can be very easily covered over with earth, and so rendered useless as lights. Even when not extinguished, the composition is of so dull a nature that its illuminating power is very small, while the area illuminated by a projectile on the ground is necessarily restricted, even under the most favourable circumstances.

A good many of the foregoing objections, if not all, were met by General Boxer in his ingenious Parachute Light Ball. It consists of a thin wrought-iron shell, containing two half-shells of wrought iron (Fig. 7), the lower of which contains a brilliantly burning composition of saltpetre, sulphur, and red orpiment, and the upper a calico parachute, the lower part of which is attached by chains to the composition hemisphere. The shell, fitted with a fuse, is fired from a mortar. The fuse is timed to explode a small bursting charge when the shell attains its maximum elevation over the area or object required to be illuminated. On the explosion of the bursting charge, the outer shell is opened, and the two inner hemispheres begin falling. The lower hemisphere, which contains the composition, being the heavier, falls more rapidly than the other, which has, indeed, received a momentary impulse by the action of the bursting charge in the opposite direction. This jerk, and the more rapid falling of the composition hemisphere, causes the calico parachute to be pulled out and expanded (Fig. 6), and it then floats the composition hemisphere slowly down over the object to be illuminated, the composition burning brightly out of a hole at the bottom of the hemisphere, for from one to three minutes, according to size. In addition to overcoming all the difficulties and objections enumerated above as belonging to the ground light ball, the parachute light ball possesses the advantages of being serviceable at sea, or to illuminate an enemy's fleet, which the ground light ball necessarily cannot be. It can also be fired from a very light and handy mortar. This construction of projectile has been very effectively employed for firework purposes.

The Smoke Ball hardly needs any mention. It is merely a paper shell filled with a composition of gunpowder, saltpetre, coal, pitch, and tallow, which when ignited emits a dense and suffocating smoke, which is stated to be useful in expelling an enemy from mines, and in concealing one's own operations. These projectiles have also served a peaceful use in the Arctic regions, where they were employed for signalling purposes—the long column of black smoke standing out prominently against the white background of these snow-clad regions.

This completes the list of projectiles for smooth-bore guns, if we except the Manby shot, for saving lives from shipwreck, and which is not to be considered a weapon of war. We will now pass forward to another section of our subject.

SEATS OF INDUSTRY.—VIII.

BY WILLIAM WATT WEBSTER.

GLASGOW.—II.

WITH the establishment of the Union, which at the time was believed by the people of Scotland to be a great national catastrophe, a great impetus was given to the trade of Glasgow; and this event also marks an important era in the manufacturing history of the city. Up to this period the foreign trade of Glasgow had been almost altogether restricted to the continent of Europe; it was now extended to the colonies. When this trade was first entered upon, the Glasgow merchants had no suitable ships of their own, and were therefore obliged to charter vessels belonging to other ports. The nature and "canny" system of the trade engaged in may be gathered from the following description taken from Gibson's "History of Glasgow:"—"A supercargo went out with every vessel, who bartered his goods for tobacco, until such time as he had either sold all his goods, or procured as much tobacco as was sufficient to load his vessel. He then returned immediately, and if any of his goods remained unsold he brought them home with him." In a very short time Glasgow became the principal centre of the tobacco trade in Great Britain, and the Virginia merchants, or "tobacco lords," as they were called, became notorious for their wealth and pride. A curious story is told of the first venture made by Glasgow merchants in the tobacco trade. In order to keep down expense, the captain of the ship sent out was appointed to act as supercargo. "This person," says the old merchant who has recorded the event, "although a shrewd man, knew nothing of accounts; and, when, on his return, he was asked by his employers for a statement of how the adventure had turned out, told them he could give them none, but there were its proceeds; and threw down upon the table a large hoggar—that is, a stocking—stuffed to the top with coin. The venture had been a profitable one; and his employers conceived that if an uneducated, untrained person had been so successful, their gains would have been still greater had a person versed in accounts been sent with it. Under this impression, they immediately dispatched a second adventure with a supercargo, highly recommended for a knowledge of accounts, who produced to them a beautifully-made-out statement of his transactions, but no hoggar." It is estimated that more than one-half of the disposable capital of the city was embarked in the tobacco trade, from about 1735 till the declaration of American Independence in 1776. A notion of the extent of this trade in its best days may be formed from the statistics for the year 1772, which show that out of 90,000 hhds. of tobacco imported into Great Britain, Glasgow alone imported 49,000 hhds. The year preceding the American War of Independence—which closed for ever the tobacco monopoly which Glasgow up to that time had enjoyed—was still more remarkable, for there were imported into the Clyde in that year no less than 57,143 hhds. of tobacco, which were the property of forty-two merchants. When the tobacco trade collapsed, the Virginia merchants turned their attention to the West Indies, and soon transformed themselves into "West India lords." Sugar cultivation in the West Indies and the introduction of cotton manufactures had opened out new paths to opulence.

It was at this period that the cotton trade of Glasgow commenced. Very shortly after the cultivation of cotton was introduced into the Southern States of the American Union, agents of Glasgow houses were established at Charlestown and New Orleans, in order to facilitate the interchange of American cotton and British manufactures. This trade was prosecuted with extraordinary vigour, and "cotton lords" soon came to take the place of the "tobacco lords" of a bygone day. It was also at this date that cotton manufacture was begun in Scotland, the first cotton-mill being built at Rothesay in 1778, by an English company; but before many years passed it was bought by Mr. David Dale, a Glasgow merchant, who became one of the most extensive cotton manufacturers in the country. The second cotton-mill built in Scotland was at Dovecot Hall, on the banks of the Leven, in Renfrewshire, and it soon proved so remunerative that it was enlarged, and five other mills were built in the vicinity. Among the earliest factories in Lanarkshire may be mentioned the celebrated New Lanark Mills, erected by Mr. David Dale, in 1785, in which Sir R. Arkwright had a share. Spinning operations were commenced in this mill in 1786, and two years later another mill was built, which was destroyed by fire before it had been completed, but was rebuilt in the following year. Subsequently two other mills were erected in the neighbourhood. From the first, Glasgow was the centre of cotton manufacturing enterprise in Scotland; and nearly the whole of the cotton goods that have been made in that country have been manufactured either by or for firms belonging to that city. Within fifty years of the time when the first cotton factory was erected in Scotland, Glasgow was the centre of about 100 cotton-mills, and before the lapse of another decade the number of cotton-mills in Scotland had nearly doubled. The increase in the imports of cotton into Glasgow during this period was, as a matter of course, proportioned to the increase in the number of mills. Thus the quantity of cotton imported into the Clyde in the year 1775 was 508 bales, or 137,160 lb.; in 1790 it was 6,500 bales, or 1,757,504 lb.; in 1812, 43,000 bales; in 1824, 54,708; and in 1834 the quantity had risen to 95,763 bales. The latter

figures represent a fifth of the cotton imported into Britain in 1834, and it is estimated that at least three-fourths of the whole quantity imported into the Clyde, or 71,777 bales, were worked up by Glasgow manufacturers.

But before the introduction of cotton, the manufacturers of Glasgow and Paisley had acquired a high reputation for the excellence of the linen fabrics they produced. Linens, lawns, and cambrics were, indeed, the staple manufacture of Glasgow till after the close of the American War. The first tape-factory in Britain was established at Glasgow by Mr. Alexander Harvey, in 1732. This enterprising citizen abducted two inkle-looms, and an experienced workman from Haarlem, at the risk of his life; and it was the Dutchman he brought over to this country who first initiated the manufacturers of Manchester into the mysteries of tape-making. As might have been expected, the cotton cloths manufactured at Glasgow when the fibre began to be used, and for some time afterwards, were of the coarsest description. A handkerchief formed of linen warp and cotton weft, which went by the name of a "blunk," was the chief article produced. It was not very long, however, before the Glasgow manufacturers attempted and succeeded in turning out a finer quality of cloth. About the year 1784, Mr. James Monteith manufactured a web of muslin from some "bird-nest" Indian yarn, and presented a dress made out of this fabric to Queen Charlotte. It was at this time that the cotton-spinning machinery of Hargreave and Arkwright was introduced into England, and as this machinery produced thread sufficiently fine for muslins, and as muslins were a profitable branch of manufacture, the Glasgow manufacturers lost no time in adopting it. In a very few years Glasgow had a large trade in plain and printed muslins, and Paisley became celebrated for fancy muslins. These goods soon came into competition with the productions of the Indian looms, for as early as the year 1793 it is stated in a report of the East India Company, on the subject of cotton manufacture in this country, that "every shop offers British muslins for sale equal in appearance and of more elegant patterns than those of India, for one-fourth, or, perhaps, more than one-third less in price." Under the date 1785, the following passage occurs in "Macpherson's Annals of Commerce:"—"The manufacture of calicoes, which was begun in Lancashire in 1772, was now pretty generally established in several parts of England and Scotland. The manufacture of muslin was begun in England in 1781, and was rapidly increased. In the year 1783 there were above a thousand looms set up in Glasgow for the production of the most beneficial article, in which the skill and labour of the mechanic raised the raw material to twenty times the value it was when imported." The spinning of cashmere yarn has been carried on at Glasgow since 1831, and merino yarn has been produced there since 1833.

It is well known that it was at Glasgow that James Watt made his first model of the steam-engine, and it was at Port-Glasgow that the *Comet* was built, the vessel that first demonstrated to Europe the practicability of steam navigation. The first steam-engine applied to the spinning of cotton in Glasgow was erected at Springfield, on the south side of the Clyde, in 1792. In the following year two power-looms were fitted up in the city by Mr. James Louis Robertson, and for a time were driven by a Newfoundland dog walking in a drum. In 1793, 40 power-looms were at work at Milton; and by 1801 Mr. John Monteith had 200 looms in operation at Pollockshaws, near Glasgow. Steam now began to be generally applied, and the number of power-loom factories increased with astonishing rapidity. In 1850 the number of spindles employed in cotton-spinning connected with and dependent on Glasgow amounted to 1,683,093; and the cotton consumed reached a total of 45,000,000 lb., or 120,000 bales; while the power-looms numbered 23,564, producing a daily average of 625,000 yards of cloth. Four years later there were from 26,000 to 27,000 power-looms in the Glasgow district, and the product was consequently proportionately increased. A return made to Parliament in 1862 shows that there were in Glasgow and its dependencies in the previous year 163 factories, with 1,915,398 spindles, 30,110 looms, giving employment to 41,237 persons. Since that year the number of factories has decreased, but the amount of production has risen notwithstanding. In 1861 the number of yards of cotton cloth exported from the Clyde was 150,754,631; in 1867, 206,394,756 yards were exported. During the Civil War in America, the trade was, of course, in a state of stagnation, but it rapidly recovered from the blow.

The great cotton manufacturing district of which Glasgow is the centre comprises New Lanark, Paisley, the Water of Leven, Kilbrachan, Johnston, Lochwinnock, Rothesay, and Old Kilpatrick. The Stanley Mills, near Perth, and the Deanstoun Mills near Doune, are also two outlying and very extensive cotton factories belonging to Glasgow, which were planted in these remote localities on account of the plentiful supply of water-power and labour. A few years ago, Mr. J. M'Donald, of Messrs. D. and J. M'Donald and Co., the eminent firm of sewed muslin manufacturers in Glasgow, stated before a committee of the House of Commons that their house employed upwards of 20,000 persons in Ireland, and that the amount of wages paid to them exceeded £3,000 per week, or about £160,000 per annum. There are upwards of thirty-five other sewed muslin manufacturers in the city—several as extensive as the Messrs. M'Donald—and it is estimated that they give employment to about 148,000 Irishwomen, who receive £1,184,000 per annum in wages. The shirtmakers of Glasgow also employ about 30,000 Irishwomen in shirt-making.

The next most important branch of trade in Glasgow is the iron trade. Forty years ago there were only sixteen smelting furnaces in the vicinity of Glasgow, with an average out-put of 2,500 tons of pig-iron each. The manufacture of malleable iron is of recent date in Scotland, and no reliable record of the quantity produced was kept till the year 1845, when it amounted to 35,000 tons. In 1854 the quantity of malleable iron produced was 125,000 tons, and of pig-iron 750,000 tons. This trade has been greatly extended since the period to which these figures refer. The most eminent of the "iron lords" of Glasgow are the Messrs. Baird, of Gartsherrie. This firm owns 42 blast-furnaces, employing 9,000 men and boys, and producing about 300,000 tons of pig-iron per annum, or about one-fourth of all the pig-iron made in Scotland. At the Gartsherrie branch of their establishment, the Messrs. Baird employ 3,200 men and boys, and make 100,000 tons of pig-iron per annum; the daily consumption of coal being upwards of 1,000 tons. Nineteen-twentieths of the coal used at this work is taken from mines within half a mile of the furnaces. For forty years the coals used at Gartsherrie were got from a mine close to the furnaces; and the iron-stone was for many years found in the immediate neighbourhood, but has now to be brought distances varying from two to twenty miles. A complete system of railway communication has been constructed for its conveyance, and the Monkland Canal is also used for the same purpose.

The fame of the iron ship-builders and marine engine-makers of Glasgow has for many years been the boast of her citizens. These trades have of recent years expanded to extraordinary proportions, and have materially contributed to the prosperity of the city. Large numbers of ocean and river steamers are yearly launched on the Clyde, and some of the finest steamships in the world have been constructed in the neighbourhood of Glasgow. The increase in the trade of the port is as remarkable as any element in the prosperity of the city, and has been dependent on the extensive improvements which have been effected on the river. About fifty years ago the depth of the Clyde opposite Glasgow was barely five feet; now it is fully twenty, and ships of the largest size can load and unload at the quays. The length of quay-wall in the harbour is about 14,000 feet. No account of Glasgow would be complete that took no notice of the chemical works of the Messrs. Tennant, which are the largest in the world, and comprise sixteen acres of ground under roof. The principal chimney-stalk at these works is 435 feet from the ground, and 450 feet from the foundation. This gigantic column has been surpassed, however, by a "stalk" erected a few years ago in its neighbourhood, which rises to an altitude of 468 feet from the foundation, and is composed of a million and a half of bricks. The principal water supply of Glasgow is obtained from Loch Katrine (a distance of forty miles), and this undertaking cost the city upwards of £900,000.

Glasgow owes no inconsiderable portion of its importance as a trading and manufacturing centre to its position in the middle of a district rich in coal and iron, the two principal factors of modern history. According to calculations made by Dr. Strang, Glasgow and its suburbs contained 446,639 inhabitants in 1861; and it is believed that the population is now considerably over half a million.

TECHNICAL DRAWING.—XXVII.

THE PROJECTION OF SCREWS (*continued*).

Fig. 255 is the plan and Fig. 256 is the elevation of a square-threaded screw, the working of which the student will understand, the system being the same as in the last study.

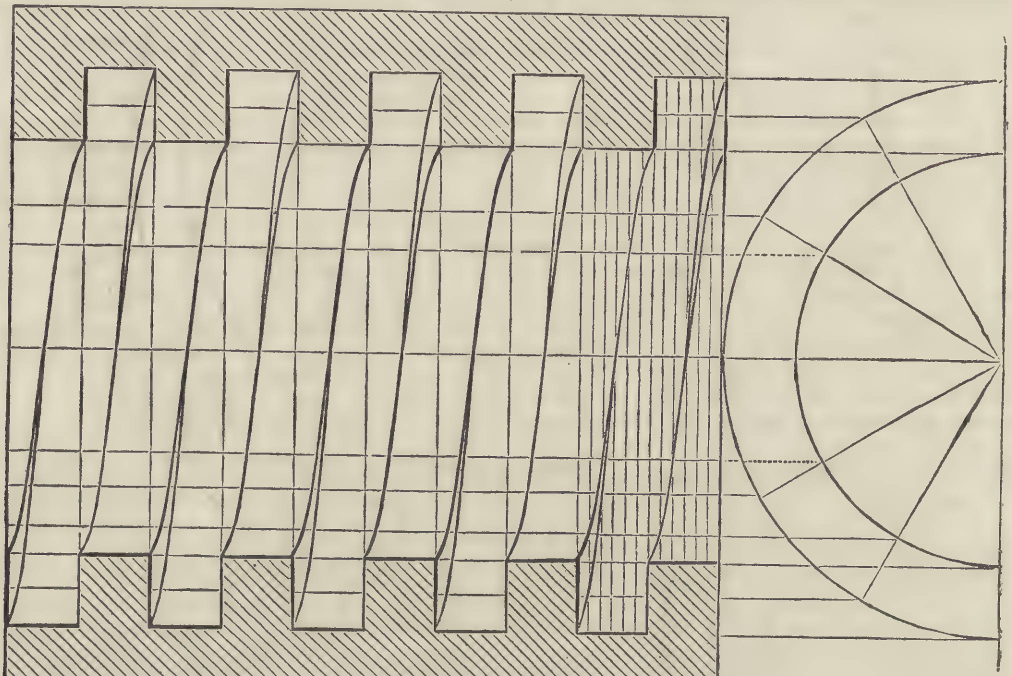


Fig. 258.

Fig. 257.

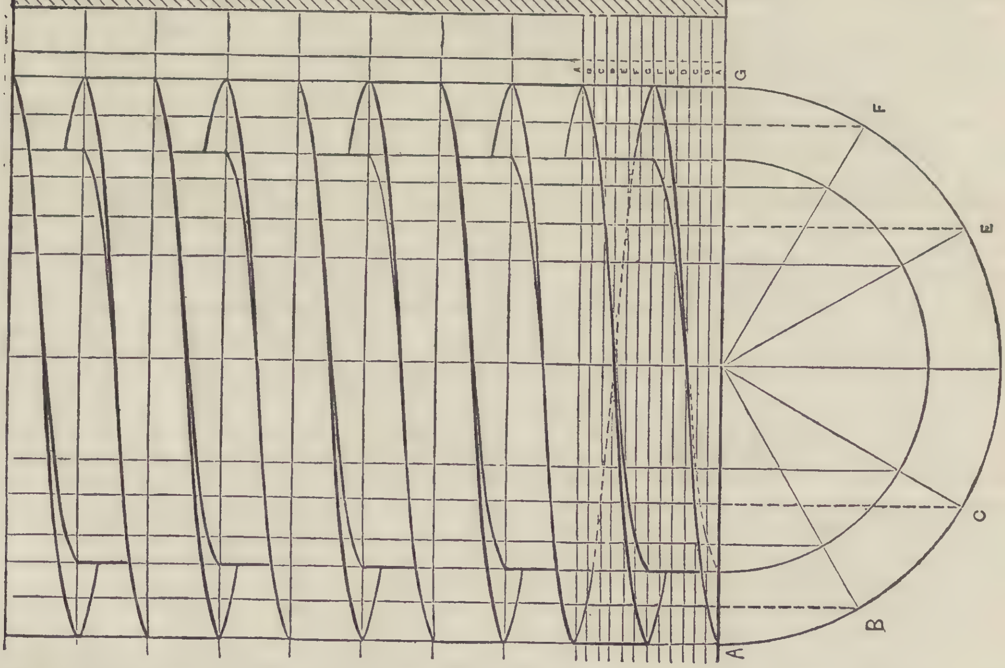


Fig. 256.

Fig. 255.

The thread and the space are equal, and the depth of the groove is the same as the width of the thread.

Having projected the first curve, which is the upper line of the thread, and having carried this helix up as far as may be required, set off the width of the thread on the perpendiculars below each of the points through which the curve has been drawn. Through the points thus obtained the lower curve of the thread may be drawn.

The points of the double helix on the inner cylinder are projected in the same manner, and therefore no further instructions will be needed.

Fig. 257 is the plan and Fig. 258 is the sectional elevation of the nut of this screw; the last is projected from the plan (Fig. 257), and the heights are carried on from the elevation of Fig. 256, the reverse curves, as before, being used. Templets for this figure may be used as in the former case.

Screws may have one, two, three, or even more threads, according to the velocity which their action may be required to produce. A double-threaded screw is one in which the pitch of any individual helix includes two threads; a three-threaded screw is one in which three threads are embraced, and so on.

Fig. 259.—This figure represents a pair of spur-wheels in

gear. The radius of the larger wheel, with 42 teeth, is $15\frac{3}{4}''$, and that of the smaller, with 24, is $9''$.

Having drawn the pitch-circles, and having set off the pitches and divided them into teeth and spaces, as already shown, draw the circles for the points and roots of the teeth; then the faces of the teeth (which in design and practice are epicycloidal, but which in drawings are approximately rendered by arcs struck with a radius equal to the pitch), and finally the flanks which are radial, but which are turned off into the circle of roots by arcs, are to be drawn.

The smaller wheel is a mere disc with teeth; the larger one has six arms.

Draw the circle representing the rim of the wheel, about as deep as the distance from the pitch-circle to the root of the teeth. Divide this circle into six equal parts, and draw radii: these will be the centre lines for the arms. Next draw the boss, central aperture for the shaft, and the key-bed; then on each side of the six central lines set off, first, half the thickness of the central ridge or flange of the arms, and then the web, by which these are strengthened.

It will be seen that the lines of the web do not run straight into the boss, or into the part supporting the rim, but turn off in each case by arcs, as already shown.

It will be observed that when wheels are in gear there are three teeth of each engaged, one tooth of each wheel touching in the pitch-line, one pair just parting, and one coming gradually into full action.

In this example the central flange of the arms and the rim, instead of running by arcs into each other, are both bevelled so as to accomplish the same end—viz., easy delivery in moulding.

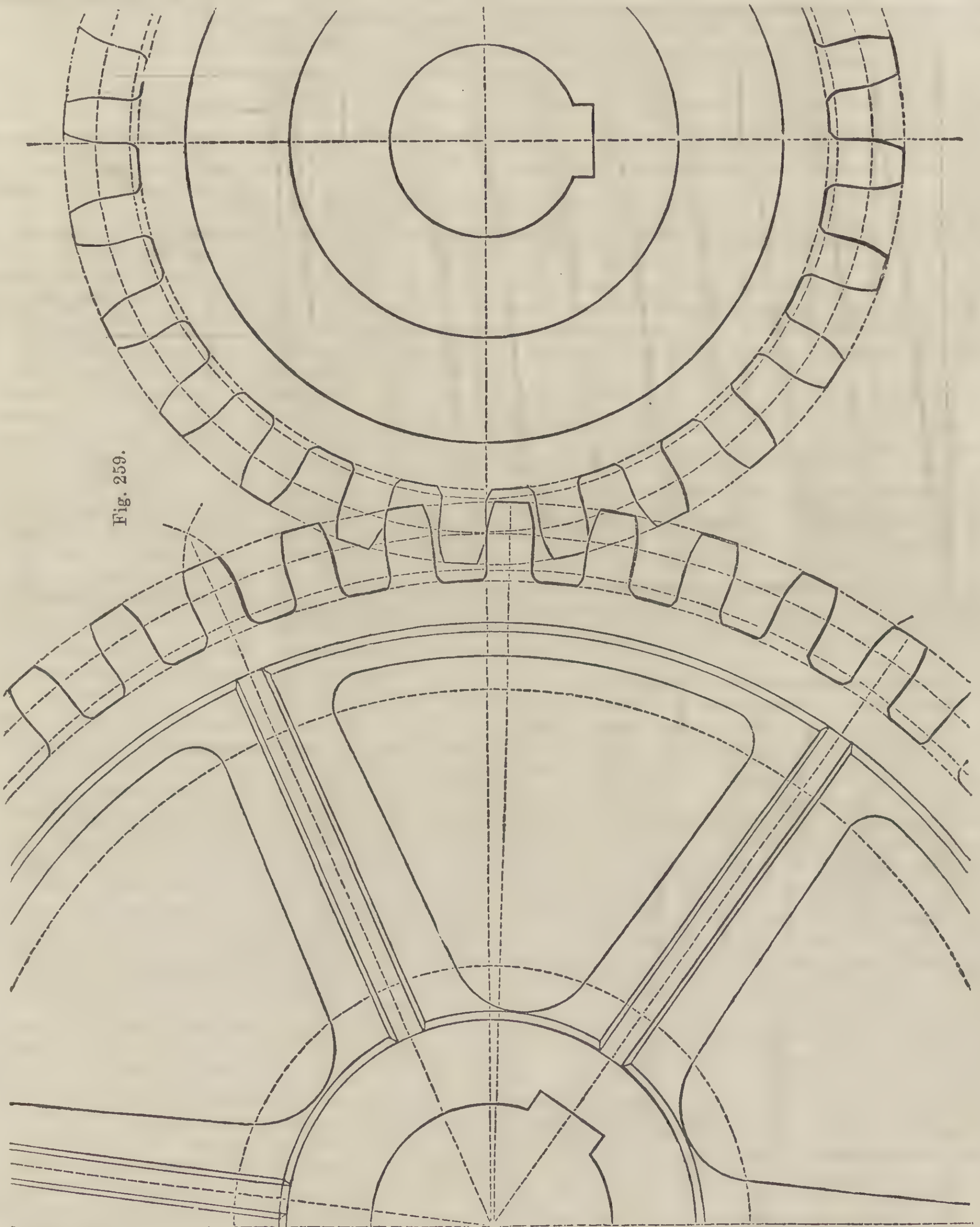


Fig. 259.

VEGETABLE COMMERCIAL PRODUCTS.

XV.

DYE PLANTS (*continued.*)

ORCHELLA WEEDS (*Roccella tinctoria*, *R. fuciformis*, and *R. hypomecha*, L.; natural order, *Lichenes*).—These lichens, which constitute the orchils of commerce, are of an ash-grey colour, having a thallus much branched, flattened, and mealy in appearance, from one inch and a half to two inches in length. The blue dye known under the name of archil or orchil is prepared from these plants, which grow on all the rocky coasts and islands of the Mediterranean, and also in the Canary Islands, Madagascar, Cape of Good Hope, and South America. The colour yielded is not in itself a fast one, but it so greatly improves others that orchil is regarded as indispensable by the dyers. The imports into this country are about 600 tons per annum.

THE TARTAR LICHEN (*Lecanora tartarea*, L.), indigenous to Sweden, Norway, and England, answers the same purpose. Litmus paper, so much used by chemists as a test for acids and alkalies, is prepared from the blue dye furnished by this lichen. Whole cargoes of it are annually brought from Sweden to Holland, where its dye, called cudbear, is the most skilfully prepared, and therefore called Dutch blue.

IV. PLANTS FURNISHING VALUABLE BUILDING AND FURNITURE WOODS.

The cultivation of wood is now carried on in several countries in Europe, where the population is considerable and the natural forests have disappeared; above all, Germany is to be distinguished for forest culture. But most wood, especially for ship-building, is still procured from those countries where the natural forests remain—viz., from Russia, Norway, Sweden, Canada, and the United States. In Germany, vast quantities of wood are annually floated down the rivers Rhine, Maine, Neckar, Weser, and Elbe, from the still productive woods of Thuringia, the Hartz, Fichtel, and Erz mountains, and the Black Forest. Russia exports a considerable amount of wood to England and the south of Europe, from St. Petersburg, Riga, Archangel, and from the Russian ports of Odessa and Cherson, on the Black Sea. Much timber is also exported to the south of Europe from Drontheim, Bergen, and Christiana, on the coast of Norway; from Göttenberg, a port in Sweden; and from Dantzic, Konigsberg, and Stettin, Prussian seaports on the Baltic. American timber is exported to the United Kingdom chiefly from Canada *viâ* Quebec, which is a great depôt for wood. The importation in 1867 of timber and wood was:—Not sawn or split, 1,211,042 loads; sawn or split, 2,177,549 loads; and staves, 62,625 loads.

Of forest productions the following deserve to be mentioned as sources of considerable trade:—

MAHOGANY (*Swietenia mahogoni*, L.; natural order, *Cedrelaceæ*) occupies the highest rank amongst the furniture woods. This is one of the loftiest and most gigantic trees of the tropics. It is indigenous to the West Indies and Central America. The mahogany tree is cut down in April and May, which is the height of the dry season; it is then squared by the adze, the branches being lopped off; and about the middle of June, when the rivers are swollen by the rains, the logs are placed on trucks and drawn by bullocks to the water-side; there they are launched into the river, formed into rafts, and so floated down the stream to the vessels awaiting their arrival.

Spanish mahogany is imported from Cuba, St. Domingo, and the Spanish Main, in logs twenty-six inches square and ten feet long. Honduras mahogany is usually lighter than the Spanish, and is imported in logs four feet square and eighteen feet long. Mahogany is chiefly valued for its colour, firmness, and durability, and the beautiful polish which it is capable of receiving. On account of these and other excellent qualities, it is particularly suitable for ship-building. Mahogany is light and buoyant, free from dry rot, and does not warp; it also suffers less from the action of shot than any other wood; since shot, when received by it, generally remains fast in the wood without splitting it.

Mahogany is extensively used in the manufacture of the best articles of domestic furniture, fancy and ornamental wood-work, cabinet-making and veneering; in fact, there are, comparatively speaking, but few persons who have not this wood constantly before their eyes, in some form or other of useful home furniture. The quantity of mahogany imported into the United Kingdom in 1866 was 53,458 tons.

EBONY (*Diospyros ebenus*, L.; natural order, *Ebenaceæ*).—This tree is a native of the Mauritius. As soon as felled the timber is immersed in water from six to eighteen months; it is then taken out, and the two ends are secured from splitting by iron rings and wedges. Mauritius ebony is imported in round sticks, like scaffold poles, about fourteen inches in diameter. It is much used for inlaying and turnery.

COLOUR.—IX.

By Professor CHURCH, Royal Agricultural College, Cirencester.

COMPLEX COLOUR-COMBINATIONS—HARMONIES OF ANALOGY—HARMONIES OF CONTRAST—HARMONIES OF SERIATION—HARMONIES OF CHANGE.

HITHERTO our studies of colours have been confined almost entirely to those which are considered elementary and those which are compounded with equivalents of their constituent primaries. We have only alluded once and again to the existence and use of the vast series of mixed hues. It is, however, chiefly in the employment of these colours that the higher chromatic developments, constituting the poetry of colour, are manifested. The obvious assortments of the primary and secondary colours, with their contrasts, resemblances, and harmonies, are not difficult to understand; but it requires a well-trained eye to discern the subtle differences and concords of composition in which several mixed hues preponderate, and a well-cultivated imagination to appreciate and to pursue their intricate delights. Here, where aid from descriptions is most desirable, it is most difficult. Endeavours to reproduce the more recondite harmonies of hues by mechanical processes are never wholly successful, and usually are even less useful than accurate verbal descriptions combined with references to natural examples. An illustration strikes us as we write. Many an observant student of Nature must have noticed the triple combination of hues presented by an old beech or elm tree as seen against the sky or clouds in early spring. We have the yellowish grey-green of the moss and lichen-grown trunk and branches standing out relieved against the dull grey of the shifting and variable clouds beyond; and this tender green of the moss and grey of the cloud are not flat or uniform, as they too often appear in our imitations of them, but fluctuating with a hundred variations of texture, quality, and tone. A few dead leaves perchance remain, suggesting, if not completing, by their brown or russet hues, the balance of colour, which just needed such idea of warmth and ruddiness as they convey.

But let us regard a little more minutely, a little longer, this natural combination of hues, which we commend, with countless others in the world around us, to every student of decorative art; let us see whether it does not possess other elements of beauty than those which we have recorded. Yes; if we look a little closer we shall doubtless see some delicate portion of nearly pure primary or secondary colour, some stray fragment of brightness—perchance an early flower or insect—just as the ancient pines of the unbroken American forest have been described as bearded with hoary lichens, yet touched with grace by the violets at their feet. So, too, there will be observed in the outermost twigs of our tree that hopeful thickening by myriads of leaf-buds, neither purple-russet nor clove-brown, nor any colour which we can definitely fix, but very beautiful in themselves and promising the verdure of summer. Deep hollows of shade, and the brightness of light will be seen too, yet sparingly, and so, like the simpler colours, made the more precious. From this example, of which nothing but the original work of a master in the art of painting could convey an adequate notion, most important deductions may be drawn. It will help us to realise, in a thoughtful, artistic way, the value of temperance in colour, as well as of balance and distribution. It will lead us to introduce, among our blues and reds and yellows, some of those rarer tints which we cannot exactly name, but which the watchful student of Nature may see trembling on the leaves of the willow, or paving the autumnal paths of the forest, or shining at eventide from the cloudy but splendid pavilions of the sun.

It behoves us now, passing from this somewhat pictorial

treatment of the obscure subject of the complex combinations of mixed hues and colours, to attempt the description and classification of harmonies of colour.

It is usual to divide harmonies of colour into two classes—those of analogy and those of contrast. Having already described the conditions under which assortments of colours become more or less harmonious, we need here do little more than illustrate by an example or two the several kinds of harmony of contrast here referred to. But it must be remembered that the distinction of harmonies into two classes is rather arbitrary. Some difference always exists between any two colours and any two tones, so that collocation, whether agreeable or otherwise, inevitably includes the element of contrast. Harmonies differ in degree or in complexity, but not in kind, so far as contrast is concerned. The ordinary harmonies of analogy pass by insensible degrees into distinct undoubted harmonies of contrast. We here cite M. Chevreul's classification of harmonies, a classification which has been adopted by most writers on colour:—

I.—HARMONIES OF ANALOGY.

1. *The Harmony of Analogy of Scale.*—This harmony is essentially the harmony of a series, or the harmony of gradation. It is produced by the simultaneous view of several tones of the same scale, and is obtained in varying degrees of perfection according to the number of the tones present and the intervals between them. When the tones are not easily separable by the eye, and run into one another, then the effect commonly called "shading" is produced.

2. *The Harmony of Analogy of Tones.*—When two or more tones of the same depth, or nearly the same depth, but belonging to different but neighbouring or related scales, are viewed together, the harmony of tone is produced. Many such assortments, however, are displeasing to the educated eye unless they be so selected as to fall into a series with a gradually increasing quantity of some one of their colour-elements, when they may be ranged in the third kind of harmonies of analogy—

3. *The Harmony of a Dominant Colour.*—This harmony is produced by viewing a landscape, a bouquet of flowers, or any contrasted colour-assortment, through a piece of glass so slightly tinctured with a colour as not to obliterate but merely to modify the natural colours of the arrangement or composition.

II.—HARMONIES OF CONTRAST.

1. *The harmony of contrast of scale* is produced by the simultaneous view of two very distant tones of the same scale.

2. *The harmony of contrast of tones* is produced by the simultaneous view of two or more tones of different depths, belonging to neighbouring or related scales.

3. *The harmony of contrast of colours* is produced by the simultaneous view of colours belonging to very distant scales, and assorted in accordance with the laws of contrast. This kind of contrast includes also those cases in which the effect is still further increased by differences of tone as well as of colour.

It must be confessed that the above classification of colour-harmonies is forced and imperfect; for every harmony depends to a greater or less extent upon contrast, either of tone or of colour, or of both; and our harmonies of analogy will be found to be derived from the milder and less startling kinds of contrast. Two ruling ideas will, however, be apparent in colour-arrangements, and upon the recognition of these ideas we may, perhaps, found a more satisfactory classification of colour-harmonies than that of Chevreul. These two fundamental ideas are those of *seriation* and *change.* Of the first we have an example in the assortment yellow, orange, red; of the latter in the assortment yellow, red, blue. Seriation or succession corresponds in some measure to the scales, and change to the chords, of musical composition. Seriation may be succession of tones or of colours, or of both; but in all cases the idea of a series, of steps, of orderly succession, with the presence of a pervading and dominant element, is the leading feature of the arrangement. In harmonies of change, on the other hand, an element common to all the members or a majority of the members is wanting; nor is there any distinct idea of orderly succession or of development in those harmonies which convey very distinctly the notion of change, more or less abrupt. Between harmonies of seriation and harmonies of change there are numberless connecting links, so that the one kind may imperceptibly slide into the latter. For beyond the regulating principles of balance, distribution, appropriateness, harmony, etc., no rigid rules, as of cast-iron, need trammel the imagination of the colourist, and so no precisely-defined classes can be arranged to receive all the possible harmonies of assorted colours and hues. What further remarks we have to make with reference to this subject we now proceed to give under the two heads of harmonies of series and harmonies of change.

Seriation, succession, development, sequence, gradation, or shading include many cases of the harmony of analogy, and are of two kinds. The tones of a scale succeeding one another in regular order furnish one example of shading; another is seen in a series of assorted colours so arranged as to convey the notion of a gradual increase of some quality in the series. The gradual development of the full leaf-green of a plant in the spring furnishes an example of gradation, not only of tones but of colours. A greenish-yellow passes into yellowish-green, this into green, and this finally acquires both depth and a greater proportion of blue. Leaves in autumn may often be observed to reverse this order, passing through various tones and hues of russet, red, orange, and yellow. The open country continually offers illustrations of the two kinds of gradation we have named, and the landscape painter, apprehending the value of this fact, is enabled to realise the relations to each other of the different parts of the view spread before him, both as regards gradation of tone and gradation of colour. In the near objects constituting the foreground he notices the extensive range of the scales both of tone and colour, and the preponderance of those hues which imply the notions of brightness and warmth. In the middle distance the range of tones and colours is more abridged; while the far distance is commonly distinguished by retiring and cold colours, with a very limited range of scale as well as of colour. From these natural examples of gradation we may take many hints useful in applying colour to decorative purposes. Supposing we wish to conventionalise a compound leaf according to the principles laid down in the "Principles of Design," we may do so not only so far as its details and form are concerned, but also in reference to its colour. Fig. 15 represents such a conventional colour arrangement—an arrangement the key to which is to be found in a natural sequence of colours often occurring in plants.

What is called a harmony of analogy runs through the series of colours in Fig. 15. The four colours there assumed to be present resemble in kind and in order those found in the spectrum of the sun to lie between the yellow and the green. The arrangement of the series conveys the idea of an increasing brightness and warmth as we descend from the pure green terminal leaflet to the smallest pair of leaflets close to the leaf-stalk. Fig. 16 represents the same series of colours in a diagrammatic way, but inverted, and furnishes us with a scientific analysis of the effects observed. The full green is represented, in accordance with the common theory, at the base of Fig. 16 as containing eight parts of blue and three of yellow. The yellowish-green comes next, with one-third less blue and the same amount of yellow as before. The greenish-yellow contains only one-third the amount of blue of the original green. Then we reach the pure yellow, which is to be regarded as the common element of the series, bringing all its members into relation.

In our next illustration (Fig. 17) the range of colour is more extensive. The series is not for general use in decorative assortments, but there are several useful lessons to be drawn from it and applied in practice. The contrasts between contiguous colours in the present example are much more startling than in Fig. 15, the intervals are larger, while the harmony is one which must be said to lie between those of analogy and those of contrast. The element of serial succession or development is weak here, that of change very apparent. The gradation in the assortment depends upon the increasing brightness of the colours as we ascend, and upon the link which connects each group of three neighbouring colours together—the presence of a common element. We arrive at this result by interposing a secondary between its constituent primaries all through its arrangement. Thus orange is placed between yellow and red, which latter is succeeded by violet, the compound of red and blue. Blue follows, and after this green; then we should re-commence the series by returning to the yellow with which it began. The analysis of the colour-

series in Fig. 17 is represented roughly in Fig. 18, where the thin lines represent yellow, a thicker line red, and the thickest line blue. Where two lines overlap, a compound colour appears.

We may, however, learn something more from Fig. 17 than is here put down. The greater development of the stalks and leaflets towards the base, with the gradually increasing pointed character of the latter towards the summit, helps to carry out the idea of series suggested by the succession of the colours. If in some minor details, such as the larger size of the second pair of leaflets, we find a break in the symmetry of the series, this is just the common feature of vegetable and animal growths by which they are in part distinguished from the mathematically accurate, but less interesting products of mere mechanism; for very often the poetry, the mystery, of beautiful organic forms lies hid in such seeming exceptions to law.

Fig. 15.

We must not fail to notice that there exist several methods of more completely harmonising the contrasted colours of such a series as that shown in Figs. 17 and 18. In copying the former figure in colours for the sake of the instruction this exercise affords, we recommend our readers to try the following generally applicable methods of bringing greater unity into such a series:—

1. An outline and veining of black, common to all the leaflets.
2. An outline and veining of gold, common to all the leaflets.
3. The addition of grey to the whole of the colours used, the largest proportion being added to the green, the least to the yellow.
4. Instead of making the secondary colours by mixture, introduce their constituent primaries by dots placed side by side.

Splendid examples of such gradations of colour as those we have been describing are to be found in numerous specimens of decorative art and manufacture in the fabrics of India,* the silks of Damascus, the *faience* of Persia, the lacquer-ware of Japan, and the porcelain of China. To take a single example, we may refer our readers to the peculiar but beautiful selection and sequence of colours upon such plates of the so-called "Persian ware" as may be seen in the Ceramic Gallery at South Kensington. The particular variety of this ware which we have now in view is known as "Damas," "Lindus," or more generally "Rhodian." The range of colours is limited except so far as one series is concerned—the series beginning with green, and passing through turquoise blue, to a pure deep cobalt, and thence to a lilac hue. The most conspicuous of the remaining colours is a dull brick-red, opaque and much raised in relief above the others. A chocolate-brown, and a black or grey like that of Indian-ink complete the list, except that now and then a specimen of the ware is found with a little yellow on it. On a ground of creamy white, conventionalised forms derived from the hyacinth, the tulip, and a few other plants occur. The leaves are filled in with a copper-green, some flowers are of deep blue touched with turquoise, others of a lilac hue. On some specimens no other colours are found than these four, yet these establish so lovely a series that it is doubtful whether the specimens which exhibit these colours only are not equal or even superior to the others. The colours of the plants represented probably suggested, in cases like the present one, some of the predominant harmonies in which the dull red, with its yellowish tincture, balances the cooler blues and greens, while the Indian-ink colour, in light circles and delicate spirals of smoke-grey, tones down the whole composition, and actually brightens and purifies its dominant series of colours. We ought not to fail to notice a most precious quality of these Persian wares—that fluctuation of colour, that absence of mechanical hardness of outline and uniformity of tone which distinguishes human handiwork of the thoughtful kind from the perfectly correct and thoroughly insipid work of a machine. But we must not linger any more over our illustrations of the harmonies of series or relation, but conclude our present lesson with a word or two on the "harmonies of change."

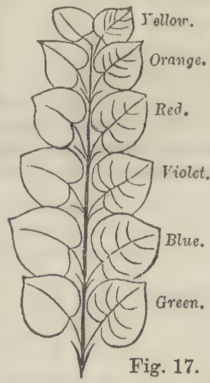
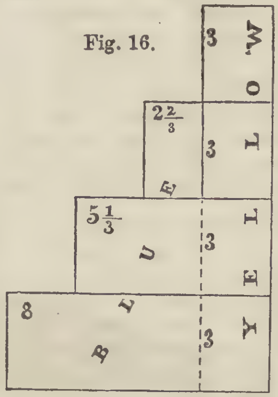


Fig. 17.

* See, for the important lessons to be drawn from the study of Oriental fabrics, Dr. Dresser's seventh paper on "Principles of Design" (Vol. I., page 230).

Fig. 16.



Harmonies in which the sequence or relationship of the constituent colours is indistinct or absent include most varieties of the harmonies of contrast. The change of tone or colour in them may vary greatly in abruptness: in the more complex assortments of this class it is very difficult to attain anything like an agreeable unity, for if there be many startling changes or contrasts, the effect becomes tiresome and spotty. The harmonies of change become more agreeable the more closely the rules of judicious distribution and balance of colour and tone are followed. The free use of separating lines of white, grey, gold, or black is often indispensable. The value of reduced tones of colour, and of the mixed and tertiary hues to modify the crudeness of a startling contrast, is very remarkable. But we have already described at considerable length, in Lessons V., VI., and VII., the principles upon which harmonious contrasts depend, and so here simply confine our attention to two illustrative examples derived from the floral world.

We might turn to the splendid family of the orchids, with their quaint forms and complex systems of colour, or we might choose one of the *Malvaceæ*, such as the *Abutilon megapotamicum*—a plant in which the green of the leaves offers a violent contrast with the red of the swollen calyces, and the five bright yellow petals of the corolla contrast again very forcibly with the violet hue of the central branch of clustered stamens—a startling assortment, but very rich in effect, when completed by the opening of the flower. In this example, besides the mere notion of contrast, we have the idea of repetition which resembles that of seriation; red contrasting with its complementary, green, and yellow with its complementary, violet, both the complementaries having, therefore, the third element, blue, in them. But every flower presenting three different colours may serve to illustrate the harmony of contrast, and we need not go far for an example. Even the quiet violet with its minute orange-tinted eye, the faint green bases of its petals and their own chief hue, somewhere between blue and red, affords a colour-assortment of the kind under discussion, the balance of which is in a measure completed when the leaves of the plant are included in the series. Similar studies of other plants should be made; it will surprise many persons to discover what a world of instruction, as well as of enjoyment, is to be derived from what we may call the chromatic analysis of flowers.

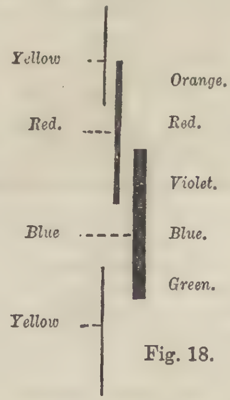


Fig. 18.

The next subjects to be discussed are the modifications of colour arising from methods of illumination and differences of structure and surface.

THE STEAM-ENGINE.—VII.

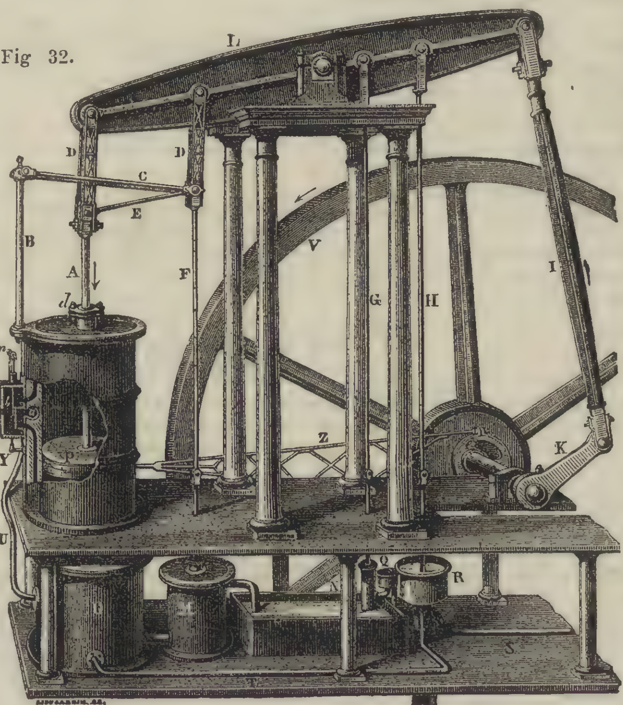
By J. M. Wigner, B.A.

BEAM—PARALLEL MOTION—CRANK—FLY-WHEEL—ECCENTRIC.

As we said in our last lesson, we shall first describe the construction of a condensing beam-engine; and Fig. 32 represents a model showing very clearly the construction and action of the different parts of an engine of this kind. In an actual engine the arrangement of the condenser, hot-well, and pumps shown on the lower base is often very considerably modified, so as to suit the exigencies of the special case, but their action is not in any way altered by this change.

A portion of the side of the cylinder is here shown removed, so as to exhibit clearly the piston and slide-valve which we have already described. L represents the "working beam," which is made very strong, and is usually of great weight. A pivot passes through its centre point, and turns in bearings supported by stout iron pillars, or, as is more commonly the case, firmly built into the masonry of the engine-house. This beam is carefully balanced, so that it may oscillate on its bearings without a great amount of force being required.

Fig 32.



The piston-rod, A, imparts motion to one end of this, and at first sight it might seem sufficient merely to fasten it by means of a pin or a common joint. We must remember, however, that the piston-rod has to move vertically up and down, and, as we shall easily see, the point of attachment to the beam moves in an arc, and does not, therefore, remain vertically over one spot. If, then, it was fastened in this way, the piston-rod would at once be bent, so that it would not act. The plan originally adopted to obviate this consisted in fixing an arc to the end of the beam, and attaching the rod to this by means of chains. This plan, however, was very clumsy, but the difficulty is fully met by the beautiful contrivance invented by Watt, and known as Watt's Parallel Motion. The piston-rod here is jointed to a compound rod, D, the other end of which is jointed to the beam.

A similar rod, also lettered D, is affixed to the beam a little way from the end, and a rod, E, is jointed to the end of these, so that a parallelogram is formed by the three rods and the portion of the beam between the pivots. The most important part of the arrangement is another rod, C, which is jointed at one end to a wall-plate attached to the building, or else, as in the figure, to a firm upright, B, affixed to some convenient part of the engine, and at the other end to one of the lower angles of the parallelogram. As will easily be seen, when the beam is nearly at the end of its oscillation, the pivots in it are nearer the centre line than when it is horizontal; the rod C, however, at these times pulls the lower ends of D, D in the other direction; and thus, when the lengths of the rods are carefully adjusted, A moves up and down in a perfectly vertical line.

To the other end of the beam the connecting-rod, I, is affixed, which imparts motion to the driving-wheel of the engine. This is accomplished by means of a crank, K, affixed to the axle of the wheel V. The connecting-rod, I, is fastened to the end of K by a pin passing through both, and turning freely in one. When in the position represented, the end of the beam to which the connecting-rod is attached is rising, and it accordingly raises the end of K, and sets the wheel in rotation. As soon, however, as the stroke of the piston is completed, and this end of the beam is at its highest point, the connecting-rod, I, and K will be in the same straight line, and it is clear that then any pressure, whether up or down, will merely be transferred to the axis of V and the bearings in which it turns, and cannot in any way tend to turn the wheel. At this point, indeed, the crank loses all its power, and ceases to act. This is apparently a great drawback, and at first sight we should suppose that it would cause the motion of the engine to be very irregular and uneven. The difficulty, however, is easily overcome. The wheel V is made with a very heavy rim, and this serves as a kind of reservoir of force. When the crank is in its most advantageous position, the tendency is to increase the speed of the engine; owing, however, to the weight of the fly-wheel, a very slight increase is produced, the power being as it were stored up in the form of momentum imparted to the wheel, and this momentum urges it past the "dead-points" as they are called, and thus renders the motion for all practical purposes quite uniform.

It is manifestly a thing of considerable importance to have the weight of the fly-wheel so adjusted as to bear a due proportion to the power of the engine. If, on the one hand, it be too heavy there will be a needless addition to the load of the engine; while if, on the other hand, it be too light, the motion will not be uniform. The practical rule is that the power stored up in it should be about equal to that produced by 6 half-strokes. Thus, if the steam exert a pressure of 1 ton on the piston, and the length of the stroke be 4 feet, the power thus generated is $6 \times 4 \times 1$, or 30 tons. The weight and velocity of the wheel should therefore be so arranged that its momentum is about equal to this. If, then, the weight of the rim be 1 ton, its velocity should be that which would be acquired by a body falling 24 feet; if it weigh $1\frac{1}{4}$ tons, it should be that acquired in falling 16 feet, and so on in proportion.

The machinery to be set in motion is usually driven by a strap passing round the fly-wheel, and then round the driving pulley of the shafting. In some cases cog-wheels are employed in place of the straps to drive the first motion.

Z is the eccentric by which motion is imparted to the slide-valve. On the axis of the fly-wheel a circular disc of metal, *e*, is keyed in such a way that the axis does not pass through its centre, but considerably to one side of it. A ring of brass surrounds this, so affixed that the disc can turn freely inside it, but cannot slip out. The rods at the side of Z are fastened to this ring, and thus as the axle rotates, carrying the disc with it, the ring is alternately moved to the right and to the left, and imparts this alternating movement to the eccentric. Behind the cylinder, and hidden by it, is a bent lever, one end of which is jointed to Z, and the other to the valve-rod, *m*; and by means of this the alternate movement of Z moves the slide-valve and regulates the supply of the steam.

The steam-pipe is omitted in the figure, but it enters the valve-casing as in Fig. 31, and the exhaust leads to the condenser O, seen under the cylinder, where the waste steam is condensed, and a vacuum thereby produced. In this way there is scarcely any resistance on the exhaust side of the piston, and the full pressure of the steam is communicated to the beam through the piston P and piston-rod.

The description of the remaining portion of the steam-engine must be deferred to our next lesson.

APPLIED MECHANICS.—X.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

THE SHEARING MACHINE AND PUNCHING MACHINE.

In the last lesson we briefly described the most important tools used in the manufacture of wrought iron—namely, the steam-hammer and the rolling mills. In the present lesson we shall describe the other tools which are of the utmost utility in the subsequent treatment of wrought iron.

The plates of iron which are produced by the rolling-mills are destined for various purposes. The best of them are employed for boilers; others are used for making iron ships, iron girders, and multitudes of minor uses. The iron plates for which the punching and shearing machines are used vary in thickness from ordinary sheet-iron up to nearly an inch in thickness.

Fig. 1.

The shearing machine, as its name indicates, is employed in trimming the edges of plates, and in cutting them to the required sizes. The punching machine is employed for the purpose of making holes in the plates, by which they can be attached together with rivets. The usual form of rivet is shown in the annexed figure (Fig. 1). It consists of a cylindrical shaft, at one end of which is a hemispherical head. The rivet is heated red-hot, and is passed through holes in the plates which are to be united together. The workman then strikes the projecting cylindrical end with a hammer, while his assistant holds a heavy tool against the head to prevent the rivet being driven out by the blow. A second hemispherical head is thus formed on the projecting end while the rivet remains red-hot, and as it cools, the contraction of the red-hot iron draws the plates together with prodigious force. The appearance two such plates present when riveted together is shown in Fig. 2.

Since this is the universal method of attaching iron plates to each other, it follows that some convenient and rapid method of producing the necessary holes in the plates is a matter of necessity. This will be evident if we remember that very many thousands of such rivets are used in the construction of an iron ship, and each rivet requires two, or sometimes a greater number of holes.

To meet this want the punching machine has been devised. It is somewhat varied in form, to meet the exigencies of different manufactures, but it is substantially in all cases a combination of two distinct mechanical principles, the fly-wheel and the lever. The latter we have already considered, and it will now be necessary to give a description of the former, and an account of the mechanical principles upon which its use depends.

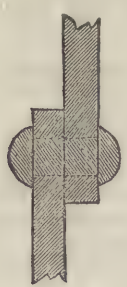


Fig. 2.

The fly-wheel is generally a cast-iron wheel, with a very massive rim. It is mounted on an axle, and has motion communicated to it by a steam-engine. The fly-wheel is strictly a reservoir of power. It is a store into which the engine pours its energy, to be withdrawn, as occasion may require, by the machine which is in use. A little consideration will be necessary in order to understand the amount of work that a fly-wheel moving with a given velocity is capable of storing up.

We have already explained in the lesson upon the hammer, that if a body whose mass contains m pounds be moving with a velocity v, the number of foot-pounds of work which have been employed to produce this velocity, and therefore the number of units of work that this body will give out before it comes to rest, is—

$$m\,\frac{v^2}{64}.$$

We shall now apply this result to determine the number of units of work in a revolving fly-wheel.

Let n be the angular velocity of the fly-wheel. The angular velocity of a body is the number of angular units through which it turns in the unit of time. Thus, for example, if we say the angular velocity of a body is 3, what is meant is, that it turns through three times the angular unit in one second. Now it will be seen, by referring to the lessons in Trigonometry, that the angular unit is 206,265 seconds; and therefore, when a body has an angular velocity of 3, it turns in one second through 206,265 × 3 seconds, and dividing this quantity by 60 × 60, we find the number of degrees through which the wheel will move in one second.

It follows, from the definition of angular velocity, that if R be the radius of the wheel, the actual velocity of any point on its circumference is nR.

If the wheel be large, we may, without appreciable error, assume all points in its rim to be moving with the same velocity.

Let m be the number of pounds in the rim. Then the mass m is moving with the velocity nR, and therefore the total quantity of work stored up in the wheel when revolving is—

$$m\,\frac{n^2R^2}{64}.$$

In order to give an application of this formula, we shall apply it to the following problem:—

A fly-wheel twelve feet in diameter, whose rim weighs four tons, revolves four times in a minute. It is required to determine the number of units of work which it contains.

Since the wheel turns round once in fifteen seconds, its angular velocity is—

$$\frac{2 \times 22}{15 \times 7} = 0{\cdot}42.$$

Therefore the velocity of the rim is—

$$0{\cdot}42 \times 6 = 2{\cdot}52.$$

We have then a mass of four tons moving with a velocity of 2·52 feet per second. The quantity of work stored up is therefore—

$$8960 \times \frac{(2{\cdot}52)^2}{64} = 889.$$

Hence 889 units of work must have been expended in order to get up this speed in the wheel, and a similar quantity will be given out before the wheel can come to rest.

It is usual, however, to give the fly-wheel a much higher velocity than in the example we have taken; and the higher the velocity, the greater the quantity of work. This will be evident from the expression for the work, viz.—

$$m\,\frac{n^2R^2}{64};$$

for this varies proportionally to n^2—that is, to the square of the angular velocity.

Hence, if we increase the speed of a wheel to double its amount, we quadruple the quantity of work that it contains. If the wheel we have been considering revolved twenty times in a minute instead of four times, the quantity would be increased 25-fold, and would become 25 × 889 units. The fly-wheel which is used in connection with a punching machine is small, but revolves with a very high velocity, and so is capable of holding a large store of work.

Let us suppose a wheel of 2 feet in diameter, whose rim weighs 2 cwt., and revolves five times in a second. The angular velocity is therefore—

$$10 \times \frac{22}{7} = 31{\cdot}4.$$

Hence the quantity of work stored in the wheel is—

$$224\,\frac{(31{\cdot}4)^2}{64} = 3451.$$

This wheel is therefore capable of raising a load of 3,451 lb. through one foot before it comes to rest, or a pressure exceeding two tons must be exerted through one foot by machinery connected with this fly-wheel before it is brought to rest.

We shall now be able to understand the use of a fly-wheel in machinery which, like a shearing machine, has occasionally to overcome a very large resistance. The engine accumulates a vast store of its energy in the rapidly revolving fly-wheel. Before the machine which experiences the resistance is in action, the motion of the fly-wheel becomes accelerated. When the machine comes into action one of three things must happen; the fly-wheel must be stopped, or the machine must be broken, or the resistance must be overcome. But

the fly-wheel cannot be stopped until it has poured forth all the energy which it contains; and, of course, the dimensions of the fly-wheel and its velocity are so proportioned that its store of energy shall be ample for the work. Nor can the machine be broken; for machines of this class are always very massive, in consideration of the vast strains to which they are liable. It follows, therefore, that the resistance must be overcome.

The general appearance of a shearing machine will be understood from Fig. 3, which is the representation of one of the

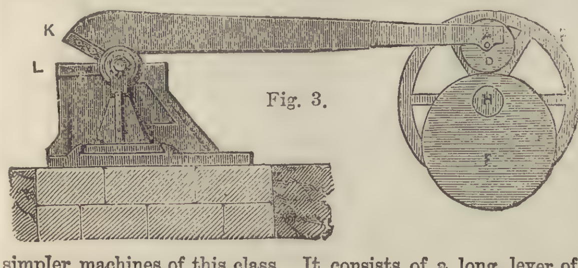


Fig. 3.

simpler machines of this class. It consists of a long lever of the first order, A C B, which has its fulcrum at C, the centre about which it turns, while the power is applied at the end A, and the resistance is encountered at the end B. At the end A is a roller, which turns around an axis, and is a means of diminishing the friction, which would otherwise be inconvenient. The roller, D, is acted upon by a cam, F. This cam consists of a circular piece of iron, which is mounted excentrically at H. As the axle H revolves the cam gradually elevates the roller, and thus applies the power to the extremity of the lever. After the roller has reached its greatest height, the weight of the lever is sufficient to bring it down when, by the revolution of the cam, its descent is possible. In this way the continuous rotation of the cam gives a reciprocating movement to the lever. At the back of the cam is shown the fly-wheel, F′. This is mounted on the same axle, H. The engine, or other source of power, which gives motion to the axle, is not shown in the figure. At the end B of the lever is one jaw of the shears, K; the other, L, is firmly attached to the stand. Whenever the roller D is raised, the jaws are closed, and the piece of iron or other body that lies between the jaws is severed.

Let us suppose that a bar of wrought iron one square inch in section is required to be sheared across. It has been found, as the result of numerous careful experiments, that an average pressure of about 20 tons is necessary. It is very remarkable that this is about the same force as would be required to tear the bar across by extension; a little consideration will, however, point out why this should be so. In each case the same number of particles of iron have to be separated from each other.

On the scale which we have used for the figure the mechanical advantage of the lever is about six-fold. Hence it will be necessary that the end A of the lever be pressed upwards with a force of about 3 tons, or a little more, in order to cut the bar across.

We shall also be able to form an estimate of the number of units of work which will be absorbed from the fly-wheel in the operation of shearing. A pressure of 20 tons—that is, of

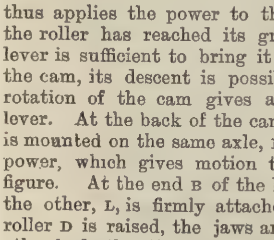


Fig. 4.

$$20 \times 2{,}240 = 44{,}800 \text{ pounds}$$

—has to be exerted through a certain distance. It is not very easy to ascertain what that distance is; it must be less than one inch. This will be evident from Fig. 4. In this A B are the edges of the shears; C D is the bar which is exposed to their action. Now it is evident that almost immediately after the cut of the shear commences the iron must be divided completely across; hence the force has only to be exerted through a space which we may certainly assume does not exceed one quarter of the total thickness to be cut. The force of 44,800 pounds has, therefore, only to be exerted through the space of $\frac{1}{48}$th part of a foot; consequently the total number of units of work is—

$$\frac{1}{48} \times 44{,}800 = 933.$$

Hence, for each operation of shearing, a number of units of work not exceeding 1,000 is abstracted from the energy stored up in the fly-wheel.

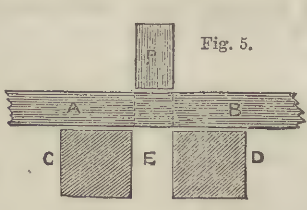


Fig. 5.

The operation of punching is in many respects analogous to that of shearing; in fact, punching consists in shearing out a cylindrical piece from a plate of iron. The important part of a punching machine will be understood from Fig. 5, in which A B is the plate of iron through which a hole is required to be made; P is the punch, which is made of hardened steel; C D is the block, and E the recess into which the piece of metal is forced from the plate.

The punch, P, is depressed, by means of a fly-wheel cam and lever, in a manner analogous to the shearing machine; the quantity of work absorbed in punching a hole can also be estimated in the manner already described.

TECHNICAL DRAWING.—XXVIII.

DRAWING FROM ROUGH SKETCHES (*continued*).

In this lesson some further examples are given with the view of affording the student additional practice in setting out work to a scale, instead of merely measuring the lines from copies.

It is again, however, necessary to mention that these are *rough* sketches, such as might be given by the head-engineer (though these would in most cases be rougher still), or as might be taken from the object, to be afterwards made into correct drawings.

The proportions are only, therefore, *generally* correct. The figures, not being drawn to any particular scale, must not be depended upon as *copies;* the subject is, therefore, to be worked according to the measurements marked upon them.

Fig. 260 is the head of a *connecting-rod* of a locomotive passenger engine.

The construction of connecting-rods generally will be found in the lessons describing the details of an engine. It is only, therefore, necessary in this place to give the names of the parts and the method of drawing them.

A is the rod-end; B, the end of the axle; C, the outside of the brasses; D, inside of the brasses; E, oil-cup; F, cotter; G, gib; H H, set-screws to keep the cotter from moving.

As usual in all objects which are symmetrical, a centre line should be first ruled.

Starting, then, with the line *a b*, and this having been made $4\frac{1}{4}''$ on each side of the centre line, the complete block forming the head of the connecting-rod is to be drawn.

The arc at the top is struck from a centre situated at *c*, whilst its meeting with the sides of the block is rounded off by two smaller arcs struck from *d*, *d*.

The lines forming the inside and outside of the brasses are now to be drawn, and the axle-end, the centre of which is $7\frac{1}{2}''$ from *a b*, and the radius of which is $2''$.

The oil-cup, gib, cotter, and set-screw will now follow, and the line *a b* is to be united to the rod-end by arcs. This example should be drawn to the scale of 6 inches to the foot, or half real size.

Fig. 261.—The subject of this lesson is a section of a *stop-cock*, drawn to about half the real size.

A stop-cock is an arrangement by which gases or liquids are allowed to pass, or are at pleasure prevented passing, through pipes, or from any receptacle in which they may be contained. They consist of A, the cock, B, the plug, and C, the handle, which in some cases forms the upper portion of the plug, placed at right angles to its axis, and in others (as the present) is simply a lever pierced with an aperture of the same shape at the top of the plug, which may be removed when desired.

Stop-cocks are generally made of brass, composition metal, or cast iron. The cock is formed with or without flanges for attachment to different pipes, vessels, boilers, etc. The above example terminates in a screw working in a plate. In this view

the tap is turned "on," so that the hole through which the liquid would pass is shown in dotted lines.

The plug is conical, so as to fit better in its seat, the part which receives it being turned out so as to correspond with the conical surface. The plug is also kept in its place by a nut D, working in a screw formed on its lower end, E.

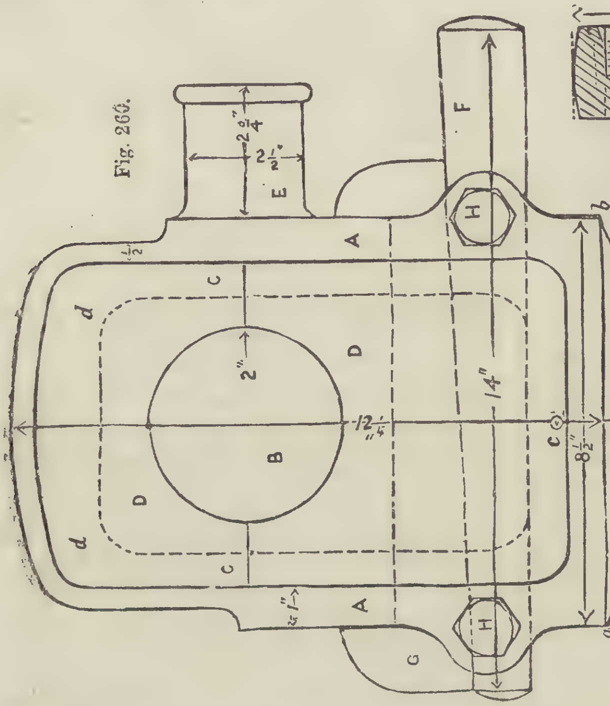


Fig. 260.

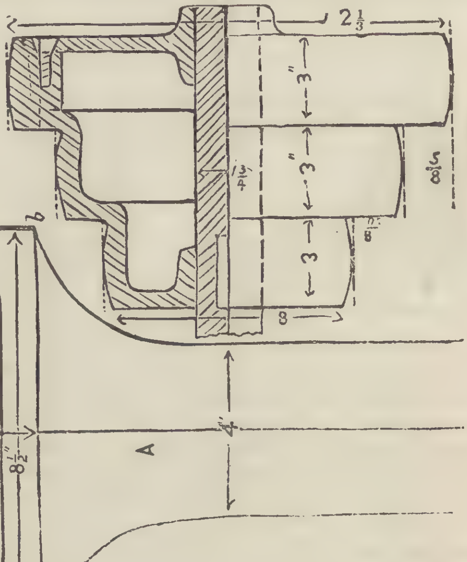


Fig. 264.

Fig. 263.

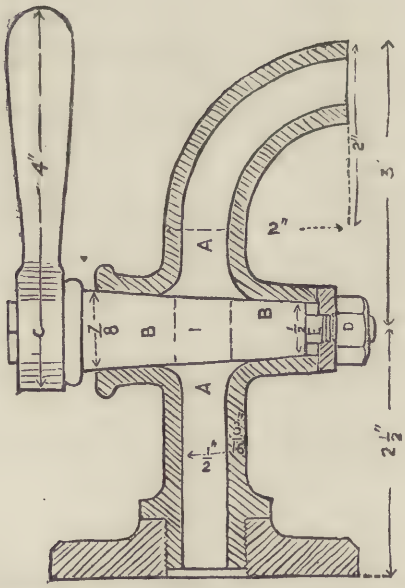


Fig. 261.

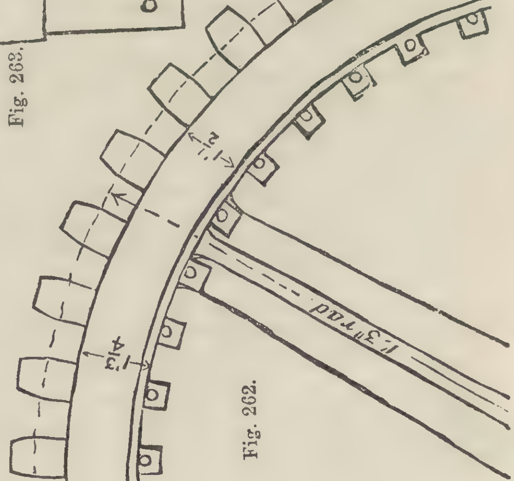


Fig. 262.

Having drawn the perpendicular from the back of the plate into which the cock is screwed, and also a perpendicular for the central line of the plug at $2\frac{1}{2}''$ from it, draw the external lines of the straight part of the tap; these merge into the quadrant struck with a radius of $2''$.

The plug is now to be drawn; its length without the flange at the top, and the screw at the bottom, being $2\frac{1}{4}$ inches; its greatest width, $\frac{7}{8}''$, and its smallest width, $\frac{1}{2}$ an inch. The handle-flanges and other details will now follow and complete the subject. The thickness of the metal is $\frac{3}{16}$. This stop-cock should be drawn to its full scale.

Fig. 262.—This is part of a *cog-wheel*—a name generally understood to mean a wheel in which the teeth are made of wood and mortised separately into an iron rim, in contradistinction to *spur*-wheels, in which the teeth are of iron, and form a part of the rim itself. These wheels were in general use in large machinery before the introduction of cast-iron wheels, and are still very common in mills. The cogs are kept in their places by pins placed inside the rims, or by keys placed between their ends. In regard to such wheels, Professor Willis says ("Mechanism," art. 55):—

"The above construction of a toothed wheel has been partly imitated in modern mill-work, for it is found that if in a pair of wheels the teeth of one be of cast-iron, and in the other of

wood, that the pair work together with much less vibration, and consequent noise, and that the teeth wear each other less, than if both wheels of the pair had had iron teeth.

"Hence, in the best modern engines one wheel of every large-sized pair has wooden cogs fitted in it in the manner just described, only, instead of employing a wooden wheel to receive them, a cast-iron wheel with mortises in its rim is employed."

In the present example the radius of the pitch is 1′ 3″ : there are 6 arms and 48 teeth. This study should be worked to the scale of 3″ to the foot.

One of the cogs is separately shown on an enlarged scale in Fig. 263.

Fig. 264.—This is a half-elevation and half-section of a *cone-pulley*, or speed-pulley. As the action of this arrangement will be fully detailed in relation to lathes, it will only be necessary to give a few hints as to the method of working out the subject. Having drawn the centre line of the shaft, set off three separate spaces of 3″ each, for the widths of wheels composing the cone. The first of these is 1′ 2½″ in diameter, and the radius of the others decreases by ⅝ in each case.

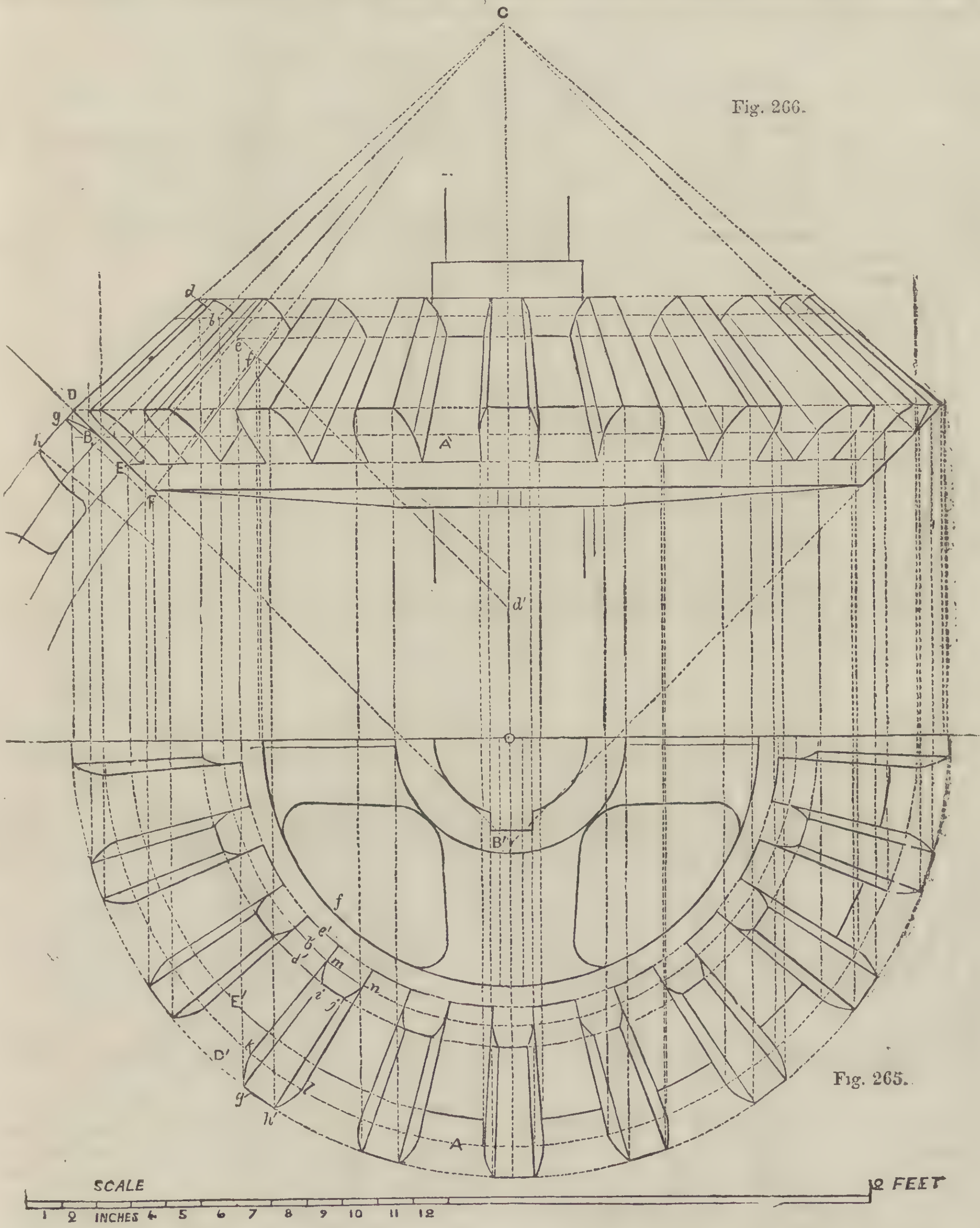


Fig. 266.

Fig. 265.

The form of the edge of each pulley is slightly convex, in order that the strap may remain upon the discs, the tendency of the belt being to rise higher rather than to slip off.

The section shows how the interior of the cone is cast, the angles being rounded in order to strengthen it. The back plate is attached by screws working in solid pieces of metal cast in the rim of the larger pulley.

This subject should be drawn to the scale of ½ of an inch to an inch.

MECHANICAL DRAWING (*continued*).

Fig. 265 is the plan, and Fig. 266 is the elevation, of a *bevel-wheel.*

It will be easily understood that, although spur-wheels are employed to transmit motion from shaft to shaft, they can only do so when the shafts are parallel to each other.

When the shafts are inclined, or form any angle with each other, the wheels must become portions of cones to roll on each other, and are called *bevel-wheels.*

In order that such wheels may work accurately, the shafts or axes of any pair working together should be situated in the same plane; in this case the axes will meet in a point which will be the apex common to both the cones of which the bevel-wheels are portions.

It is sometimes, however, convenient that the axes of the bevel-wheels should pass close to each other, without intersecting: they are then known as *skew-bevels.*

When the cones are equal and the axes are at right angles, they are called *mitre-wheels.*

In Fig. 265, A is the pitch-circle, or base of the cone of which the mitre-wheel is to form a frustrum; and in Fig. 266, A′ is the elevation projected by perpendiculars from it.

From both ends of the line A′ (as B) draw lines at 45°, meeting in a point B′ on the central perpendicular.

Now with radius B′ B describe an arc which will be a portion of the development of the cone forming the underneath side of the bevel-wheel; each bevel-wheel being, as it were, made up of frustra of two cones meeting the point of the teeth; the apex of the one being at B′, and of the other at C, obtained in the same manner, by drawing lines at 45° to the elevation of the pitch-circle.

Divide the pitch-circle, A, in the plan into pitches, and set off in these the teeth and spaces. At B, draw a tooth as it would really be if the surface of the cone were developed or spread out.

Lines drawn from the point, the root, and base of the rim to C, will give the points D, E, and F on the line B. From these points draw horizontal lines which will give the elevations of the circles on which the points and roots of the teeth will be situated, and of the base of the rim.

Project the elevations D and E on the plan—viz., the semicircles D′ and E′. The plan of the circle of which F is the elevation, F not being required in this view, is omitted.

From D (on each side) draw a line to the apex, C, and on this set off D d, the length of the teeth. This is generally taken at two, or two and a half pitches (the former in the present example).

From d draw a line parallel to D F—viz., d d'. From B, E, and F draw lines to C, cutting d d' in b, e, f. From these points draw horizontals, which will give the elevation of the pitch-circle, points, and roots of the teeth at the narrow end of the bevel-wheel. Project these into the plan, and so obtain the semicircles d', b', e', f.

Set off within the teeth around the circle D′ in the plan, the width of the point g h, taken from the development shown at the side of the elevation—viz., g' h'—and from these points draw lines to the centre of the plan; these radial lines extending only between the circles D′ and d', as g' i and h' j.

Join g' and h' by means of arcs to k and l (the widths of the teeth already set off), and from k and l draw as far as the circle e', the root of the teeth, passing through the pitch-circle of the upper end of the teeth in m n.

Join m and n to i and j, and this will complete this portion of the plan.

It only remains now to project all the points of teeth, as g' h', on the line D (Fig. 266), by carrying up perpendiculars from the plan to meet the corresponding lines in the elevation. This is shown by dotted lines in the illustration. The arms and shaft are then to be added in plan and elevation.

A scale of feet and inches is appended to Figs. 265 and 266, from which the diagrams have been constructed, and which may be used by the learner to ascertain the relative dimensions of the different parts of the bevel-wheels as shown in the diagrams. His own drawing, however, should not be made from the scale that we have given, but from one of his own construction, the measurements in the diagrams being ascertained from our scale, and then made in his own drawing from his own scale.

AGRICULTURAL DRAINAGE AND IRRIGATION.—VII.

By Professor WRIGHTSON, Royal Agricultural College, Cirencester.

WATERING LAND BY ARTIFICIAL MEANS.

THAT the practice of irrigating, or artificially watering land, has been practised from the most ancient times, there is no doubt. It would occupy more space than we can afford, as well as carry us into questions which it is not our object to discuss, had we to give a detailed history of the art. It must, therefore, suffice to mention that in Egypt, where the annual overflow of the Nile early taught the lesson, in Persia, in Palestine, as well as in India and China, and later, in Roman agriculture, irrigation occupied an important place. In hot and arid countries, indeed, it is positively essential, while in the more temperate climates of Western Europe it is a valuable means of increasing the productiveness of land. This practice outlived the fall of Roman civilisation, and under the direction of the monks of the Middle Ages was carried on with success. It is supposed by some authors to have been introduced by the Moors into Spain, and from thence to have been re-introduced into other parts of Southern Europe; but more probably it lingered in England, as well as in parts of France, Spain, and Italy, from the time of the Romans, and as civilisation progressed, and greater attention was devoted to the arts of agriculture, its extension would be secured.

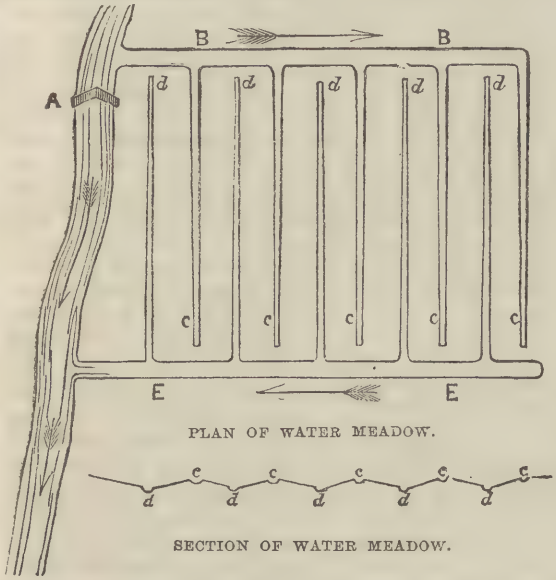
In Italy irrigation is carried out on a truly grand scale. The waters of the Po, the Adige, the Tagliamento, and all the minor streams are employed for this purpose, and there is no country which possesses a greater extent of rich water-meadow than Lombardy. The entire country, from Venice to Turin, has been spoken of as one great water-meadow, and yet irrigation is not there confined to grass lands, but is used in the cultivation of rice, vines, and other crops.

Public attention was first called to the importance of irrigation in this country by Robert Vaughan, who published a work in 1610, entitled so lengthily, that we only give the first few words:—"Most Improved and Long-experienced Water-works: containing the Manner of Summer and Winter Drowning of Meadow and Pasture," etc. Among the earliest established water-meadows are those of Wiltshire and Hampshire, which were made between 1700 and 1710. These meadows were not, however, laid out upon the best principle, and subsequently underwent considerable improvement. In the latter part of last century the subject of irrigation was again taken up in a treatise by George Boswell, published in 1780, and a series of papers followed by the Rev. T. Wright, of Auld, in Northants, published from 1789 to 1810. Instances are also on record in which irrigation was used in the cultivation of corn as well as grass in two parishes of Forfarshire and Aberdeenshire; but until very recently it was almost exclusively applied to grass in England, and the history of irrigation in Scotland dates from even a later time. In 1794-5 the Highland and Agricultural Society brought a practical irrigator from Gloucestershire, and several extensive proprietors set an example by forming irrigated meadows.

The subject of irrigation is extensive, and when we remember its various phases, and the numerous questions connected with the soils and situations where it may be employed, the waters most suitable for the purpose, the grasses and other plants which it benefits most, and the general management of water-meadows and irrigation works, it will be seen that there is material for volumes. Add to this the important aspect of irrigation as connected with the utilisation of the sewage of our towns, and some idea will be obtained both of the importance and extent of the subject. In these pages we propose to touch briefly upon all the above points; but especially upon the last, namely, the utilisation of sewage.

With reference to the various kinds of irrigation, the water may be applied either upon the surface, or from beneath. Superficial irrigation may be natural, as in the proximity of rivers which periodically overflow their banks; or artificial, by which is meant the conveying of water by channels so arranged as to distribute water evenly over the surface of land. The methods of doing this are controlled by the contour of the ground. In most cases the land is formed into beds or broad ridges, raised in the centre. The water is brought by a main "carriage," or ditch, and is allowed to flow into shallow trenches along the tops of the ridges. These trenches being full, overflow, and the

water trickles down the sides of the ridges, finding its way into gutters provided for the purpose between the elevated "panes" or "stetches." The meadow is so laid out that while the carriage gutters on the tops of the ridges bring the water on to the meadow, the gutters in the hollows between the ridges serve to carry it off into the brook at a lower level. The accompanying figure will render this arrangement plain.



A, dam across river; B, main carrier; c, watering gutters; d, draining gutters; E, main draining gutter.

Where the land has a uniform slope the "catch-water" system of irrigation may be followed. In catch-water meadows the water is allowed to flow on to the most elevated portion of the ground by means of a "feeder," and as it overflows, and seeks a lower level, it is again collected by a second feeder, which crosses the line of greatest declivity, and re-distributes it over a still lower tract. Thus the water finds its way across a succession of feeders, each of which is a new point from which it is distributed. In either of these two methods "stops" are used in order to control the flow of the water, these stops being composed of boards placed across the feeders, or of sods placed so as to block the passages, and cause the water to overflow at the particular point required. Water-meadows may be formed wherever there is a constant supply of water, in dry as well as moist seasons, where the water is not required for mills or other purposes, and where the water "rights" are clearly defined so as to allow of the appropriation of the stream for the purpose of irrigation.

The clearer the water, the better for the purpose, and this at once marks a distinct difference between "warping" and irrigation. The former operation is in use in the extreme south-east of Yorkshire and north-east of Lincolnshire, in the proximity of the Humber. This and other rivers carry down vast quantities of mud from the interior of the country to the sea, the result being a deposition of alluvial material at their joint estuary. So considerable is this accumulation, that a long tongue of newly-formed land prolongs the south-east extremity of Yorkshire far into the ocean, and a lighthouse has been removed nearer to the sea three times within a very short historic period. This then is a case of natural warping, and by directing the flow of mud-charged waters on to lands adjacent to the river, the deposition is regulated according to the requirements of man. The rise and fall of tides assist in this operation, enabling successive floods of water to be poured over the portion of land embanked for warping. Thus, in a year, from one to three feet of soil of superior quality is accumulated.

In irrigation, the presence of mud or other *suspended* matter in the water is not desirable, since the deposition of fine particles on the leaves of growing plants would interfere with their functions and retard their growth; while substances in a state of *solution* are absorbed by the soil and the roots of plants, and minister to their wants. In an earlier paper we contrasted the two operations of drainage and irrigation, and at this point it may be well once more to point out the true functions of water when used for the latter purpose. Stagnant water, the enemy against which the drainer strives, is a "dog in the manger," uselessly occupying the interstices of the earth, keeping out the air, and, by its evaporation, rendering the land cold. In irrigation, on the other hand, it is essential that the field should be in the first place cleared of stagnant water, either by natural or artificial means. It must be dry, or drained. Next, from time to time a sheet or layer of moving water is allowed to find its way over its surface, carrying with it nourishment for plants, in many cases a higher temperature, and dissolving and rendering available the mineral wealth of the soil. Such, in few words, is the theory of irrigation.

Let us now glance very briefly at the general management of such meadows. The water is allowed to flow over the surface in winter and in summer, and provision is made for this by a proper arrangement of sluices. According to Mr. George Stephenson, the meadow should be periodically watered from October to January. Each watering is continued for fifteen to twenty days without intermission, and at the expiration of each of these periods the ground should be made completely dry for five or six days, *to give it air*. Mr. Bravinder, of Cirencester, who has the most intimate knowledge of the working of these meadows, says they "produce (after the winter's watering) an early and abundant supply of grass for ewes and lambs, and other stock, which is exceedingly useful in the spring. The custom is to consume the first crop by keeping sheep on the land till May, when other grass and green crops are ready to take the stock. The water is then turned on again, and subsequently a second crop is produced, and mown for hay about the latter end of June or beginning of July. The water is turned on a third time, and the aftermath which succeeds is fed off, which generally lasts till Christmas."

In all this, great care is requisite in keeping the water-courses clear, and regulating the "stops," so as to cause the water to flow evenly over the entire surface. Again, in severe frosts the watering must be discontinued, as by persisting in allowing water to flow at such times the temperature of the ground will be injuriously lowered. Usually, in districts where water-meadows obtain, a considerable extent of them is committed to the care of an experienced man, who both keeps the channels in good order and regulates the supply of water.

In conclusion we must briefly notice one of the most bold attempts at irrigation, under difficulties, ever attempted in this country. Mr. Campbell, of Buscat Park, Gloucestershire, conceived the idea of pumping water from the Thames (which skirts his property) to the highest point of his estate, and allowing it to fall from thence by gravity, and fertilise a large area of land. In order to carry out this scheme, a "plant" of no ordinary kind was required. A gigantic undershot wheel was placed across the Thames, which is not a very formidable river at that point; three powerful pumps, worked by the said wheel, were erected for the purpose of sending a constant stream of water by large iron piping up to a reservoir, or artificial lake, twenty-five acres in extent and sixty feet deep, scooped in the Oxford clay. Descending from this huge reservoir are delivery-pipes, carrying the fertilising fluid to those parts of the estate where it is required, and where it is further distributed over the surface. Some hundreds of acres have thus been irrigated, and splendid crops of Italian rye-grass have been the result, giving food to an immense number of sheep. Such is a very general sketch of the system of irrigation proposed, and, to a great extent, now in operation at Buscat Park. It is a grand idea, carried out with immense energy and great expenditure of capital. Whether suitable to the climate of this country, or likely to be remunerative, are questions which time alone can answer. In the case now under consideration the results obtained have been satisfactory, as exhibited in the production of heavy crops of Italian rye-grass, which would not have been nearly as good had it not been for the fertilising properties of the water which was thus boldly diverted from its original course, and turned over the land. It still remains, however, to be seen if the increased crops thus obtained will afford a sufficient return for the great outlay necessary in the first instance.

PRINCIPLES OF DESIGN.—XII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

DECORATIVE DESIGN.

BEFORE we pass from a consideration of furniture and cabinet work generally, we must notice a few points to which we have as yet merely referred, or which we have left altogether unnoticed. Thus we have to consider upholstery as applied to works of furniture, the materials employed as coverings for seats, and the nature of picture-frames and curtain poles; we must also notice certain general errors in furniture, strictly so called. When examining certain wardrobes and cabinets in the International Exhibition of 1862, I was forcibly impressed with the structural truth of one or two of these works. One especially commended itself to me as of a fine structural character, while of classic formation. Just as I was expressing my admiration, the exhibitor threw open the doors of his well-formed wardrobe to show me its internal fittings, when, fancy my feelings at beholding the first door bearing with it, as it opened, the two pilasters that I conceived to be the supports of the somewhat heavy cornice above, and the other door bearing away the third support, and thus leaving the superincumbent mass resting on the thin sides of the structure only, while they appeared altogether unable to perform the duty imposed upon them. "Horrible! horrible!" was all I could exclaim.

Some of the most costly works of furniture shown by the French in the last Paris International Exhibition were not free from this defect; and this is strange, for to the rightly constituted mind this one defect is of such a grave character as to neutralise whatever pleasure might otherwise be derived from contemplating the work. We see a man, a genius perhaps—a man having qualities that all must admire; but he has one great vice—one sin which easily besets him. While the man has excellent and estimable qualities, we yet avoid him, for we see not the excellences but the vice. It is so with such works of furniture as those of which we have been speaking, for their defects are such as impress us more powerfully than their excellences.

Respecting these works of furniture, this should be said: they are more or less imitative of works of a debased art period—of a period in which structural truth was utterly disregarded—yet this is no reason why we should copy the defects of our ancestors.

Infinitely worse than the works just spoken of, is falsely-constructed Gothic furniture, where the very truthfulness of structure is openly set before us. Not long since I was staying with a client whose house is of Gothic style. Being about to furnish drawings for the decorations of this mansion, I was carefully noting the character of the architecture and of the furniture, which latter had been designed and manufactured expressly for the house by a large Yorkshire firm of cabinet-makers. The structure of the furniture appeared just, the proportions tolerably good, the wood honest, and the inlays judicious; but, can it be imagined, the whole was a mere series of frauds and shams—the cross-grain ends of what should be supports were attached to the fronts of drawers, pillars came away, and such falsity became apparent as I never before saw. How any person could possibly produce such furniture, be he ever so degraded, I cannot think. I have seen works that are bad, I have seen falsities in art, but I never before saw such falsity of structure and such uncalled-for deception as these works presented. The untrue is always offensive; but when a special effort is made at causing a lie to appear as truth, a double sense of disappointment is experienced when the untruthfulness is discovered.

In his work on "Household Taste," to which we have before alluded, Mr. Eastlake objects, and I think very justly, to the character of an ordinary telescopic dining-table. He says: "Among the dining-room appointments, the table is an article of furniture which stands greatly in need of reform. It is generally made of planks of polished oak or mahogany, laid upon an insecure framework of the same material, and supported by four gouty legs, ornamented by the turner with mouldings which look like inverted cups and saucers piled upon an attic baluster. I call the framework insecure, because I am describing what is commonly called a 'telescope' table, or one which can be pulled out to twice its usual length, and, by the addition of extra leaves in its middle, accommodate twice the usual number of diners. Such a table cannot be soundly made in the same sense that ordinary furniture is sound; it must depend for its support on some contrivance which is not consistent with the material of which it is made. Few people would like to sit on a chair the legs of which slid in and out, and were fastened at the required height by a pin; there would be a sense of insecurity in the motion eminently unpleasant. You might put up with such an invention in camp, or on a sketching expedition, but to have it and use it under your own roof, instead of a strong and serviceable chair, would be absurd. Yet this is very much what we do in the case of the modern dining-room table. When it is extended it looks weak and untidy at the sides; when it is reduced to its shortest length the legs appear heavy and ill-proportioned. It is always liable to get out of order, and from the very nature of its construction must be an inartistic object. Why should such a table be made at all? A dining-room is a room to dine in. Whether there are few or many people seated for that purpose, the table might well be kept of an uniform length, and if space is an object it is always possible to use in its stead two small tables, each on four legs. These might be placed end to end when dinner parties are given, and one of them would suffice for family use. A table of this kind might be solidly and stoutly framed, so as to last for ages, and become, as all furniture ought to become, an heirloom in the family. When a man builds himself a house on freehold land, he does not intend that it shall only last his lifetime; he bequeaths it in sound condition to posterity. We ought to be ashamed of furniture which is continually being replaced; at all events, we cannot possibly take any interest in such furniture. In former days, when the principles of good joinery were really understood, the legs of such a large table as that of the dining-room would have been made of a very different form from the lumpy, pear-shaped things of modern use."

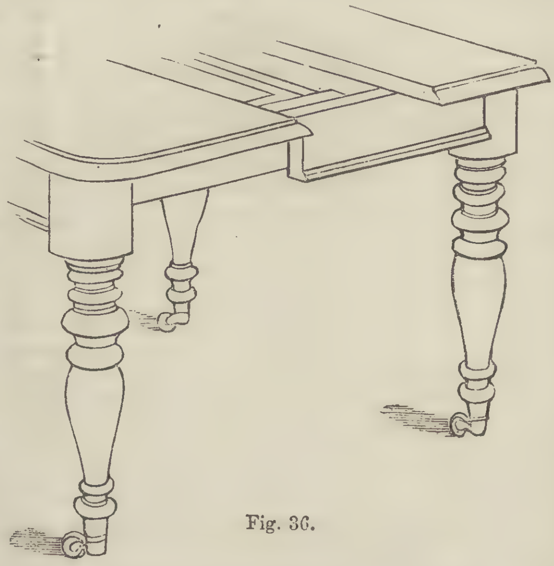


Fig. 36.

In nearly all these remarks I agree with Mr. Eastlake, and especially in his remark that, owing to the very nature of its construction, a modern dining-table must be an inartistic object. No work can be satisfactory in which any portions of the true supporting structure or frame are drawn apart; and this occurs to a marked degree in this table, as is shown in Mr. Eastlake's illustration, which we here copy (Fig. 36).

Another falsity in furniture is veneering—a practice which should be wholly abandoned. Simple honesty is preferable to false show in all cases; truthfulness in utterance is always to be desired. It was customary at one time to veneer almost every work of furniture, and even to place the grain of the veneer in a manner totally at variance with the true structure of the framework which it covered. This was a method of making works, which might in their unfinished state be satisfactory, appear when finished as most unsatisfactory objects. Since this time much progress has been made in a knowledge

of truthful structure and of truthful expression, yet this method of giving a false surface by means of veneer is not wholly abandoned as despicable and false.

A few months back I had occasion to visit a cabinet warehouse in Lancashire, and the owner called my attention to the fine grain of some old English oak, and remarked that certain pieces of furniture were of solid wood. Upon investigation, however, I discovered that while the furniture in question was made throughout of oak, the bulk of the structure was of common wainscoting, and the surface was veneered with English oak. I confess that I would much rather have had the furniture without its false exterior, and daily my love for fine grain in wood gets less. I think that this arises from the fact that strong grain in wood takes from the unity of the work into which it is formed, and tends to break it up into parts, by rendering every member conspicuous. What is wanted in a work of furniture, before all other considerations, is a fine general form—a harmony of all parts — so that no one member usurp a primary place —and this it is almost impossible to achieve if a wood is employed having a strongly-marked grain.

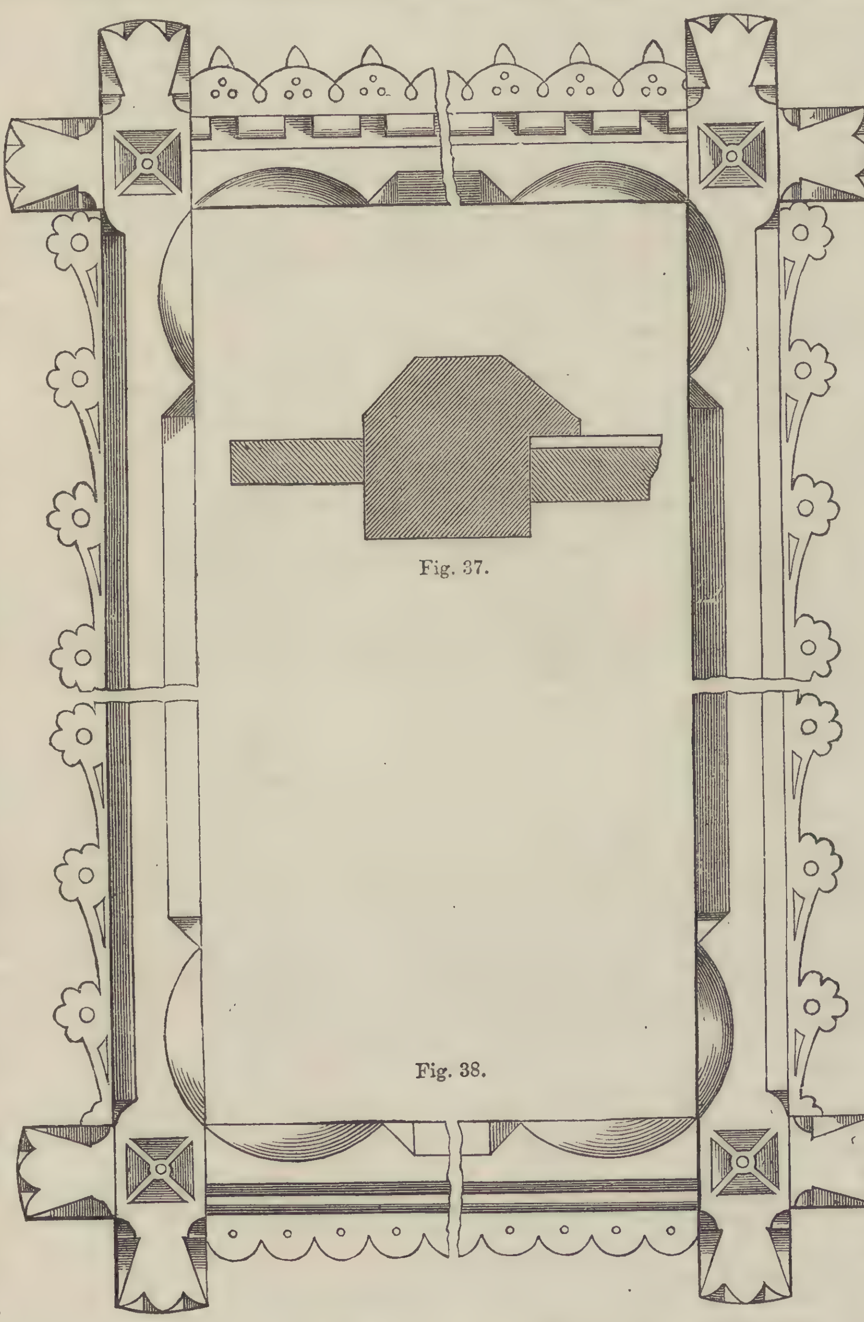


Fig. 37.

Fig. 38.

With us a room is considered as almost unfurnished if the windows are not hung with some kind of drapery. The original object of this drapery was that of keeping out a draught of air, which found its way through the imperfectly fitting windows; and the antitype of our window-hangings was a simple curtain, formed of a material suitable to achieve the purpose sought. Such a curtain was legitimate and desirable, and would contrast strangely with the elaborate festooning and quadrupled curtains of our present windows. We daily see yards of valuable material, arranged in massive and absurd folds, shutting out that light which is necessary to our health and well-being; and a pair of heavy stuff curtains and a pair of lace curtains to each window, each curtain consisting of sufficient material to more than cover the window of itself. An excess of drapery is always vulgar, and a little drapery usefully and judiciously employed is pleasant.

Many windows that are well made, and thus keep out all currents of air, need no curtains. If the window mouldings are of an architectural character, and are coloured much darker than the wall, so as to become an obvious frame to the window, and thus do for the window what a picture-frame does for a picture, no curtains will be required. I have recently had a wonderfully striking illustration of this. Two adjoining rooms are alike in their architecture: one is decorated, and has the window casement of such colours as strongly contrast, while they are yet harmonious, with the wall. Before the room was decorated, and the windows were thus treated, a general light colour prevailed, both on the wood-work and on the walls of the room, and curtains were hung at the windows in the usual way. With the altered decorations, the windows became so effective that I at once saw the undesirability of re-hanging the curtains, and yet not one of all my friends has observed that there are no curtains to the windows; while if the curtains are removed from the adjoining room, where the window-frames are as light as the walls, the first question asked is, "Where are your curtains?"

Curtains should be hung on a simple and obvious pole. All means of hiding this pole are foolish and useless. This pole need not be very thick, and is better formed of wood than of

metal, for then the rings to which the curtains are attached pass along almost noiselessly. The ends of the pole may be of metal, but I prefer simple balls of wood. The pole may be grooved, and any little enrichments may be introduced into these grooves, providing the carving does not come to the surface, and thus touch the rings, which by their motion would injure it. Whatever is used in the way of enrichment should be of a simple character, for the height at which the curtain pole is placed would render very fine work altogether ineffective.

As to upholstery, I would say, never indulge in an excess. A wood frame should appear in every work of furniture, as in the examples we have given. Sofas are now made as though they were feather beds; they are so soft that you sink into them, and become uncomfortably warm by merely resting upon them, and their gouty forms are relieved only by a few inches of wood, which appear as legs. Stuffing should be employed only as a means of rendering a properly constructed seat comfortably soft. If it goes beyond this it is vulgar and objectionable. Spring stuffing is not to be altogether commended; a good old-fashioned hair seat is more desirable, as it will endure when springs have perished. As to the materials with which seats may be covered I can say little, for they are many. Hair cloth, although very desirable, is altogether inartistic in its effect. Nothing is better than leather for dining-room chairs; Utrecht velvet, either plain or embossed, looks well on library chairs; silk and satin damasks, rep, and many other fabrics are appropriate to drawing-room furniture, and upholsterers will find a new three-coloured material, called "The Windsor Brocade," manufactured by Messrs. Warde, of Halifax, useful for such purposes. Chintz I am not fond of as a chair covering, and in a bath-room I would rather have chairs with plain wooden seats than with cushions covered with this glazed material.

With a mere remark upon picture-frames I have done. Picture-frames are generally elaborately carved mouldings, or are simple mouldings covered with putty ornaments, which, whether carved or formed of putty, are overlaid with gold leaf; they are, indeed, highly ornamented gilt mouldings. I much prefer a well-formed, yet somewhat simple, black, polished moulding on the interior of which runs a gold bead. For prints and water-colours the annexed frame (Fig. 37) is all that can be desired. A fanciful yet good picture-frame was figured in the *Building News* of September 7th, 1866, which we now repeat (Fig. 38).

VEGETABLE COMMERCIAL PRODUCTS.

XVI.

VALUABLE BUILDING AND FURNITURE WOODS (*continued*).

EAST INDIAN EBONY (*Dalbergia latifolia*, L.; natural order, *Leguminosæ*).—The real raven-black ebony, one of the heaviest and hardest of all woods, and which in the fineness of its texture resembles ivory, is derived from this tree, which is indigenous to the island of Ceylon, and is also found in Java, Sumatra, and the Manilla Islands. This ebony is used for wind instruments and the keys of pianos.

The alburnum, or sap-wood of both the mahogany and ebony trees, is white and valueless, and is chipped off with the adze before the logs are shipped. The indurated heart-wood of these trees is the only part of the stem fit for industrial and economic purposes.

A great deal of ebony comes into commerce from the Cape of Good Hope, and arrives in England in sticks of about three to six feet long, and two to four inches thick.

BOXWOOD (*Buxus sempervirens*, L.; natural order, *Euphorbiaceæ*).—This is an evergreen shrub, a native of Southern and Western Europe. The wood is dense, compact, and admirably suited for wood engravers and also for the formation of graduated scales and fine works of art. It is imported in pieces four feet long and ten inches in diameter from Smyrna, Constantinople, and the Greek Islands. The fine saw-dust of this wood is sold at Nuremberg and other places as pounce, which dries writing quickly. The annual imports are between 3,000 and 4,000 tons.

SANDAL WOOD (*Santalum album*, L.; natural order, *Santalaceæ*).—This tree, which produces the beautifully perfumed sandal-wood, is a native of India and China. Sandal-wood is much used for entomological cabinets, as its fragrance is a preservative from insects. In China it is employed as incense, and is manufactured into toys. The shavings and saw-dust of sandal-wood are valuable in perfumery.

LIGNUM VITÆ (*Guiacum officinale*, Plum.; natural order, *Zygophyllaceæ*).—This is the hardest and heaviest wood known. It is of a dark olive colour, and cross-grained, the fibres running obliquely into one another, in a form somewhat resembling the letter X, so that it cannot be split with an axe, and is therefore divided by the saw. The tree is forty feet high, and four or five feet in circumference, with numerous knotted, much divided branches, abruptly pinnate leaves, and bright blue flowers. It grows in tropical America, especially in Jamaica, where it is very abundant, and whence our supplies are chiefly obtained. The timber of this tree is very valuable, where strength and durability are needed and weight is no object. Lignum vitæ comes over in billets about three feet in length and a foot in diameter, and is chiefly used for ship-blocks and pulleys. It takes a fine polish, and turns well, and for this reason is used by turners for articles requiring a hard close-grained wood.

BIRD'S-EYE MAPLE (*Acer saccharinum*, L.; natural order, *Aceraceæ*).—This tree is a native of North America, where it grows from Canada to Georgia. In early spring it yields, when tapped, an immense quantity of sugar. The beautiful wood known as bird's-eye maple, so much admired in cabinet work, is obtained from this species.

AMERICAN CEDAR (*Cedrela odorata*, L.; natural order, *Cedrelaceæ*), a native of the West Indies and Central America. This tree furnishes the wood used for the boxes in which cigars are packed, and for the inside portions of furniture.

PENCIL CEDAR (*Juniperus Bermudiana*; natural order, *Coniferæ*).—A North American tree, which furnishes the red wood for lead pencils.

LANCE-WOOD (*Duguetia Quitarensis*, St. Hilary; natural order, *Anonaceæ*).—This tree furnishes lance-wood, which is used by coachmakers for the shafts of gigs and other vehicles where both strength and elasticity are required. We receive lance-wood from Cuba and Guiana, whence it comes in the form of poles, fifteen to twenty feet in length and six to seven inches in diameter.

ROSEWOOD (*Triptolemœa* and *Dalbergia*; natural order, *Leguminosæ*).—Several undetermined species of these genera of trees furnish rosewood. We receive this wood from Brazil, in planks about twelve feet in length, flat on one side and rounded on the other, each being evidently one-half of the stem, with the bark removed. Violet-wood and king-wood, which come to this country also from the Brazilian forests, are probably only other species of the same plant, as both resemble the rosewoods. They are in much smaller pieces, usually in round sticks four or five feet long and from two to six inches in diameter. The best rosewood comes from Rio de Janeiro, and has recently been ascertained to be chiefly the timber of *Dalbergia nigra*. Rosewood is much used for library and drawing-room furniture, and is so named because, when fresh, it has the odour of a rose. The imports into England in 1863 were 2,120 tons.

BLACK WALNUT (*Juglans nigra*, L.; natural order, *Juglandaceæ*).—This is a large tree, indigenous to North America. Previous to the introduction of mahogany and rosewood, walnut was held in high estimation in the manufacture of costly furniture. It is still imported for furniture, although to a less extent than formerly, and is now chiefly employed in the manufacture of the stocks of all kinds of fire-arms.

SNAKEWOOD (*Piratinera Guianensis*; natural order, *Artocarpaceæ*).—This is a very beautiful ornamental wood, of a rich chestnut-brown colour, mottled with cloudy amber-coloured spots, resembling the markings of serpents—a scarce wood, imported from South America in sticks, two or three inches in diameter, and five or six inches in length. When dry, snakewood readily takes fire if rubbed against wood harder than itself, and is so used for obtaining fire by the native Indians.

SATIN WOOD (*Swietenia chloroxylon*, L.; natural order, *Cedrelaceæ*).—This is a handsome, hard, yellow veneering wood, occasionally imported from India, the West Indies, and South America, in logs seven or eight inches square and ten feet in length. It is used by cabinet-makers and upholsterers in inlaying work, and for picture-frames.

The far greater proportion of our building timber consists of the wood of various coniferous trees, which we import from America, Northern Europe, and Switzerland. The deal used in

carpentry is the wood of several species of pine and fir. Thus, white deal is furnished by the Norway spruce fir (*Abies excelsa*, L.), and yellow deal by the Scotch fir (*Pinus sylvestris*, L.); the silver fir (*Abies picea*, Link.) furnishes a whitish deal used for flooring. There are numerous others, as the American and European larches (*Larix Americana*, Michx., and *L. Europœa*, L.), and the hemlock spruce fir (*Abies Canadensis*, Michx.), which are employed for ship and house building. We can only mention them, and we must now leave this branch of our subject, as we have not space for further selection. The names only of the trees—European, Asiatic, African, American, and Australian—which yield valuable furniture and building materials would form quite an extensive catalogue.

V. PLANTS PRODUCING VALUABLE GUMS, RESINS, AND BALSAMS.

The substances now to be considered are distinguished as follows:—

Resins are the inspissated or thickened juices of plants, and are commonly associated with an essential oil; they are insoluble in water, but are dissolved by alcohol and essential oils.

Gum Resins or *Balsams* are partly soluble in water, from the quantity of gum they contain.

Gums are soluble in water, but not in alcohol.

BALSAM FIR (*Abies balsamifera*, Michx.; natural order, *Coniferæ*).—This tree furnishes the Canada balsam so much used in mounting microscopic preparations of objects of natural history, as it not only preserves, but at the same time gives them transparency. This oleo-resinous fluid is contained in blisters of the bark, which are punctured, and the balsam is then caught as it exudes. It is imported from America.

INDIA-RUBBER, GUM-ELASTIC, or CAOUTCHOUC, is the hardened milky juice of many euphorbiaceous plants and others. That from the Brazils is the produce of *Siphonia elastica* (Rich.), a noble tree, growing to a height of sixty feet, with a light, stone-coloured bark. That collected in Central America, and now an important article of export all along the Atlantic seaboard, is obtained from *Castilloa elastica*. The Brazilian method of obtaining the caoutchouc, or india-rubber, is to spread the milky juice upon clay moulds, and dry it in the sun or in the smoke of a fire, which blackens it. The moulds are in the form of balls, bottles, and shoes. The juice is collected from incisions made in the stem, and is received into a cup of clay placed under the wound. It flows freely, to the extent of about four ounces daily from each tree. This juice is then smeared over the clay moulds in successive layers, which are dried separately, until a sufficient number have accumulated to give a proper thickness; the clay is then washed out, and the india-rubber is ready for the market.

In Central America the juice is collected from incisions made in the stem, and is received into vessels. A tree four feet in diameter will yield twenty gallons of juice, each gallon producing two pounds of good dried rubber; and an industrious man will collect twenty-five gallons a day. The milky juice is strained through a wire sieve, so as to exclude all impurities before it is transferred to barrels, in which the real manufacture of the rubber is performed. The best manner of converting the milk into rubber is by mixing with it the juice of a certain vine, termed by the natives *achuca*, which has the singular property of producing coagulation within the space of five minutes. About a pint of the infusion of the vine is well mixed with every gallon of the milk. This is done in a large tin pan, and the rubber separates as a soft mass from the brown liquid. This mass is then placed on a board, slightly pressed by hand, and rolled out with a piece of heavy wood. A great quantity of water is thus squeezed out, and the rubber, which has now assumed its elasticity, is made into flat round cakes a quarter of an inch thick, twenty inches in diameter, and perfectly white in colour. Hitherto the greater portion of the caoutchouc imported has been received from South America, but latterly a considerable amount has come from Singapore, Assam, and other places in the East Indies. This is the product of the *Ficus elastica*, L. (natural order, *Urticaceæ*), or the famed banyan tree, so celebrated for its pillared supports, "whose daughters grow about the mother tree," and which has furnished the motto "*Tot rami quot arbores*" to the Royal Asiatic Society. But this product is nevertheless very inferior to that furnished by the Brazilian india-rubber tree.

Caoutchouc is contained in the juices of many tropical trees, and in small quantities in many plants of temperate regions; it seems to form an essential part of the milky juices which are characteristic of the *Euphorbiaceæ*, *Apocynaceæ*, and *Urticaceæ*.

In 1864, 71,027 cwt. of caoutchouc were imported into the United Kingdom in the raw state—viz., from South America, 52,097 cwt., valued at £389,576; and from the East Indies, 11,930 cwt., valued at £113,069. The same year, our exports of caoutchouc to Europe and the United States were 29,107 cwt., valued at £205,932. The total import for 1867 was 79,756 cwt.

GUTTA-PERCHA (*Isonandra gutta*, Hook.; natural order, *Euphorbiaceæ*).—This is a magnificent tree, sixty or seventy feet in height and from five to six feet in diameter, growing in the Malayan Archipelago. Gutta-percha is the inspissated juice of this tree, and is procured as follows:—The trees are felled, the bark removed, and the milky juice which is found between the bark and wood is collected and poured into a trough made from the stalk of the plantain-leaf. It quickly coagulates on exposure to the air, and is then kneaded into cakes for exportation. Gutta-percha is one of the most valuable vegetable productions ever discovered. It is in its natural state hard, rough, dry, opaque, tough, inflammable, and slightly soluble. On immersion in hot water it becomes softened and capable of being moulded into any figure, which it retains when cold; a number of pieces, too, may be united so perfectly as to show no mark whatever of their junction. It is not elastic, but so tough that a thin slip, one-eighth of an inch in substance, will sustain a weight of forty-two pounds. A great variety of articles are made from gutta-percha, and, above all, cables for the conveyance of the submarine telegraph, which, without this invaluable substance, could not have existed.

The demand for gutta-percha is continually increasing, and it is certain that a process too destructive to the trees is adopted in the endeavour to furnish the requisite supply.

In 1864 the gutta-percha imported amounted to 36,750 cwt.; and, at the very lowest estimate, not fewer than 300,000 trees were destroyed to obtain that amount. A short time ago this tree was abundant on the island of Singapore; now few if any other than small plants are to be found there, all the large trees having been felled. The range of its growth appears, however, to be considerable, as it doubtless extends over all the islands of the Malayan Archipelago.

TAR (*Pinus sylvestris*, L.; natural order, *Coniferæ*).—Tar is an impure turpentine, viscid, and brown-black in colour, procured by destructive distillation from the roots of various coniferous trees, particularly the above species. This process was known to the ancients, being described by Theophrastus, and is nearly the same now as in his time.

A bank is chosen near a marsh or bog, as the roots of pines so situated always yield the greatest supplies of tar; in this bank a conical cavity is formed, the sides of which are beaten down and rendered as firm as possible with heavy wooden mallets. A cast-iron pan is placed at the bottom of the hole or funnel, with a spout which projects through the side of the bank, and barrels are placed beneath this spout to collect the tar as it comes away. This cavity is then filled with the roots of the pine, which are cut and neatly packed so as to fill up the entire space, and the whole is covered over with turf and beaten down with the mallet or stamper. The roots in the inside of the cavity are then set on fire, and the tar, as it distils, runs down the sides into the iron pan, passing through the spout into the barrels, which, as fast as filled, are bunged, and are then ready for exportation.

Tar is used chiefly by seamen, for preserving cordage and wood from the effects of the atmosphere. Nearly all our tar comes from Russia, Norway, and Sweden; the United States, also, supply us with a considerable amount; the forests between Bayonne and Bordeaux in France, the Black Forest, and the forest of Thuringia, in Germany, send large quantities into commerce. In 1851, 24,000 tons were received into this country.

Pitch is tar condensed or deprived of the more volatile parts by distillation. The tar is boiled in an open iron pot until all the volatile matters are driven off; the residuum remaining is pitch. This is a black, solid, and glossy substance, very brittle when cold, but softening and becoming ductile when heated. That used in this country is mostly home manufactured. Pitch is frequently mixed with tar, and used for similar purposes, in ship-building, for caulking the seams of vessels, etc.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—VII.

THE CYCLOID (*continued*).

THE *involute*, *cycloid*, *epicycloid*, and *hypocycloid* curves are much used in drawing the exact curves forming the teeth of wheels working in racks or in gear with each other; and these will therefore be more fully worked out in the lessons on "Technical Drawing."

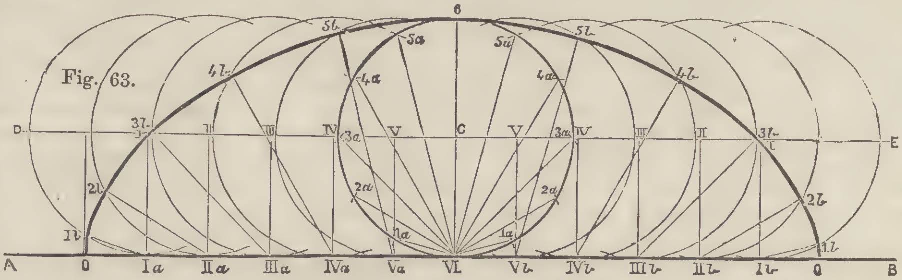


Fig. 63.

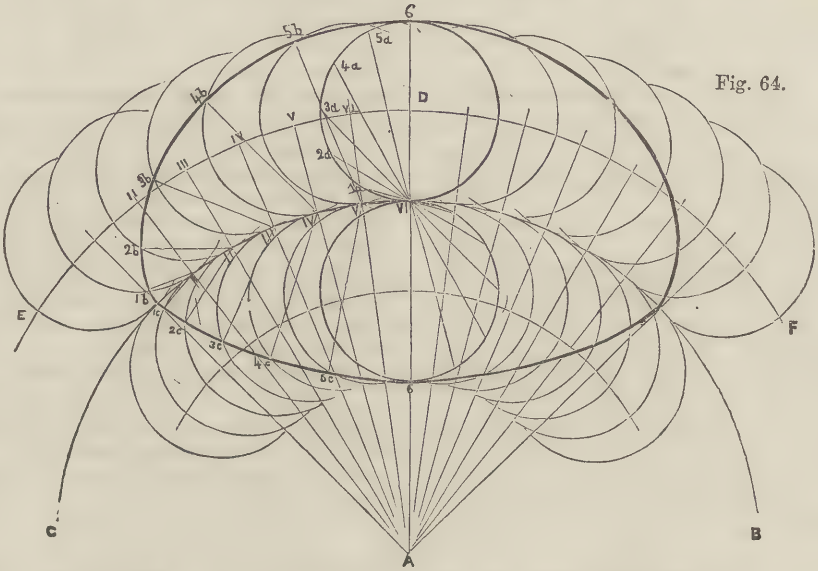


Fig. 64.

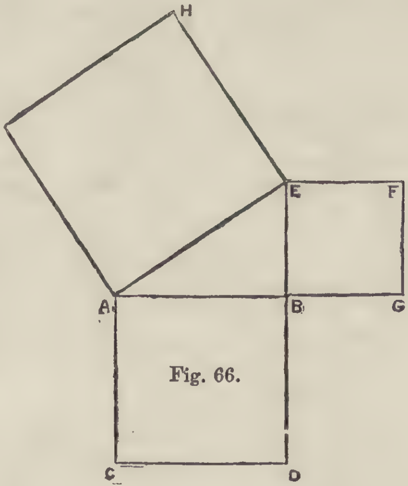


Fig. 66.

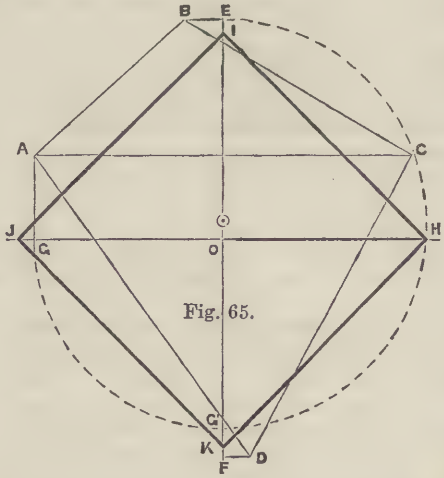


Fig. 65.

The cycloid was invented by Galileo, an eminent mathematician and natural philosopher. He was born at Pisa in 1564, and died in 1642.

To describe the cycloid.

Draw the director A B, (Fig. 63), the generating circle C, and a line through the centre, called the line of centres, D E, parallel to A B.

Draw the diameter VI 6, and divide each half of the circle into any number of equal parts—viz., 1*a*, 2*a*, etc.

On each side of point VI, set off the lengths V*a*, IV*a*, III*a*, etc., and V*b*, IV*b*, III*b*, etc., equal in size and number to the divisions in the circle.

From O, I*a*, II*a*, III*a*, etc., erect perpendiculars, cutting the line D E in I, II, III, etc.

From each of these points describe circles equal to the generating circles. From V*a* set off on the circle of which V is the centre the length of the line VI 5*a*—viz., 5*b*. Mark off the same length on the corresponding circle, from V*b*. From IV*a* set off on the circle drawn from centre IV the length of the line VI 4*a*, and do the same on the corresponding circle from IV*b*.

Proceed thus, setting off the lengths of the lines VI 3, 2, and 1, on the circles resting on the points numbered correspondingly (in Roman figures), and through the points marked on the various circles—viz., 1*b*, 2*b*, 3*b*, etc.—draw the curve.

THE EPICYCLOID AND HYPOCYCLOID.

When a circle, instead of rolling along a straight line, rolls around the edge of another circle, any point in it will describe the curve known as the *epicycloid* (Fig. 64).

To describe the epicycloid.

Draw the directing circle B C, and the generating circle D.

From A, with radius A D, describe the circle of centres E F.

Divide the generating circle into any number of equal parts, 1*a*, 2*a*, etc., and set off these lengths from VI on the *directing* circle C B—viz., the points marked I, II, III, etc., in the larger Roman figures.

From A draw lines through I, II, III, etc., cutting the circle E F in i, ii, iii, etc. (smaller Roman figures).

From each of these points, as centres, describe circles similar to the generating circle.

From points v, iv, iii, ii, i, set off on the circles resting on them the lengths VI 5*a*, 4*a*, etc.; and through the points thus obtained — viz., 1*b*, 2*b*, 3*b*, etc. — the epicycloid is to be drawn.

When the generating circle rolls *inside* instead of outside the directing circle, the curve traced is the *hypocycloid* (Fig. 64).

It is constructed in precisely the same manner as the *epicycloid*, excepting that the lengths VI 5*a*, etc., are set off from V, IV, III, etc., *inside* instead of outside the directing circle; and the points 5*c*, 4*c*, 3*c*, etc., are thus obtained.

If the *diameter* of the generating circle were equal to the *radius* of the directing circle—that is, if vi 6 extended to A—a

point in the generating circle, instead of generating a *curve*, would trace a *straight line.*

To construct a square equal in area to a given quadrilateral figure, A B C D (Fig. 65).

Draw the diagonal A C, and bisect it by a perpendicular.

From B and D draw lines parallel to A C, and cutting the perpendicular in E and F. Draw a line bisecting E F in O, and from A draw a line parallel to E F, and cutting this bisecting line in G. Find a mean proportional between O E and O G—viz., O H.

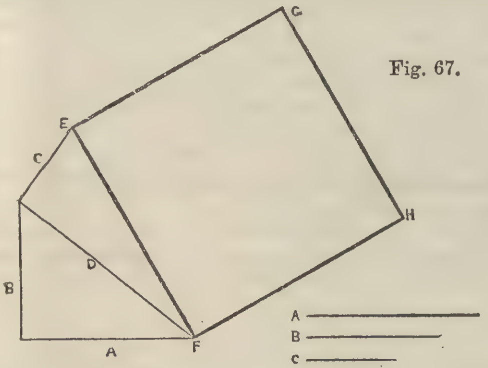


Fig. 67.

Set off the length O H (the semi-diagonal) from O on E F and O G—viz., I, J, K. Join H I J K, and the square will be equal to the quadrilateral figure A B C D.

To construct a square which shall be equal in area to two other squares added together (Fig. 66).

Place the two squares so that a side of the one, as A B, shall be at right angles to one side of the other, as B E. Draw the line A E.

Now, according to Euclid (I. 47),* "In any right-angled triangle, the square which is described upon the side subtending the right angle, is equal to the squares described upon the sides which contain the right angle." And it will be seen that A B E is a right-angled triangle, and that the squares A B C D and B E F G are described upon the sides of it which contain the right angle; and therefore the square A E H I, which is described on (the

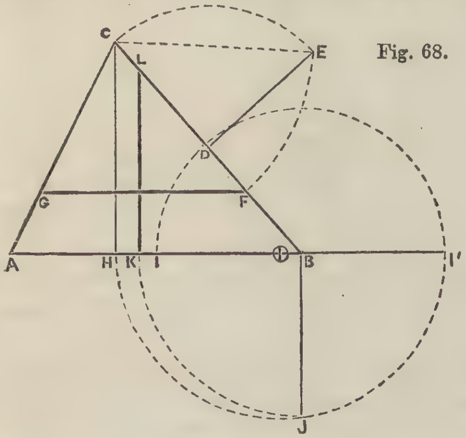


Fig. 68.

hypothenuse) A E, which subtends the right angle, is equal to the sum of the two other squares.

To construct a square equal in area to any number of squares added together (Fig. 67).

This is done by merely carrying on the process shown in the last figure. Let it be required to construct a square, which shall be equal to the areas of the three squares of which A, B, and C are the respective sides. Place B at right angles to A, then the hypothenuse D would be the side of the square equal in area to the squares constructed on A and B. Place C at right angles to D, draw E F, and construct a square upon it; then E F H G is equal to the squares constructed on C and D, and therefore equal to the squares constructed on all three lines. Any number of squares may be thus added together.

To divide a given triangle, A B C, *into two equal parts by a line parallel to one of its sides* (Fig. 68).

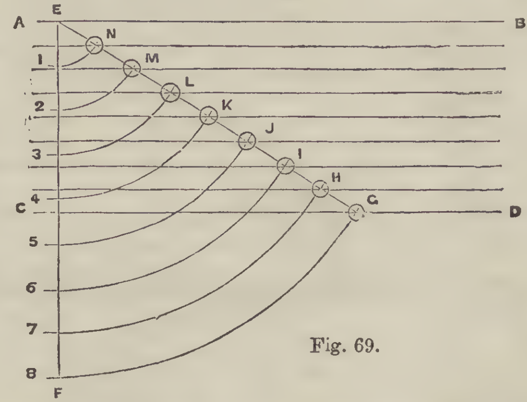


Fig. 69.

Bisect one of the sides, as C B, in the point D, and erect the perpendicular D E equal to D C. From C, with radius C E, describe an arc cutting C D in F. From F, draw F G parallel to A B, which will divide the triangle into two parts of equal area.

To divide a triangle into two equal parts by a line perpendicular to one side (Fig. 68).

From C, draw C H perpendicular to A B. Bisect A B in I.

Find a mean proportional between B H and B I—viz., B J.

From B, set off B K equal to B J, and the perpendicular K L will divide the triangle as required.

To divide the space contained between the lines A B *and* C D *into equal parts, by means of lines parallel to* A B (Fig. 69).

Draw the line E F perpendicular to A B, and set off on it equal lengths corresponding to the number of spaces into which A B C D is to be divided—viz., 1 to 8. These spaces may be *any* size, but must be *equal.* From E, with radius E 8, describe an arc cutting C D in G. Draw E G. From E, with radius E 7, E 6, E 5, etc., describe arcs cutting E G in H, I, J, K, L, M, N.

Draw lines parallel to A B through these points, and the space will be divided as required.

To draw a circle of a given radius, which shall touch another given circle and a straight line (Fig. 70).

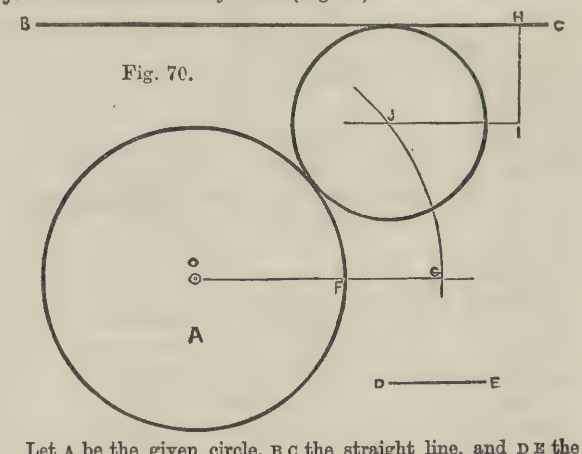


Fig. 70.

Let A be the given circle, B C the straight line, and D E the radius of the required circle. The question here is, to find a point which shall be the centre of a circle of a given radius, which shall touch the given circle and straight line. From O, the centre of the given circle, draw a radius and produce it. From the periphery of the circle, and on this radius, set off F G, equal to D E. From O, with radius O G, describe an arc. At any point, as H, in B C, draw a perpendicular, H I, equal to D E. From I draw a line parallel to B C, cutting the arc drawn from O in J. From J, with the required radius, describe a circle, which (if the work has been *accurately* done) will touch the given circle and straight line.

* This proposition is said to have been discovered by Pythagoras, a disciple of Thales, who, after travelling in India and Egypt in pursuit of knowledge, settled in Tarentum, in Italy, where he founded the celebrated Pythagorean school, 550 years B.C.

PRACTICAL PERSPECTIVE.—VI.

Fig. 28 is a perspective view of a strong table or bench, the edge of the top of which is "flush" with the legs and surrounding rail.

Having drawn the picture line and horizontal line, and having fixed the centre of the picture and point of distance, place the point B (the nearest angle of the table) at the required distance on the left or right of the spectator.

From B set off B C′, equal to the complete length of the table, and from B and C′ draw lines to the centre of the picture.

On the other side of B set off B D, the width of the end of the table, and from D draw a line to the point of distance (not shown in this figure), cutting B C in D′.

From D′ draw a horizontal line, cutting C′ C in E. The figure C′ E D′ B will then be the perspective view of the area covered by the table. From B and C′ mark off on the picture line B G and C′ F equal to the thickness of the legs, and from G and F draw lines to the centre of the picture, cutting D′ E in G′ and F′.

Now on the other side mark off B H equal to B G, and from D set off the same width—viz., D J. From H and J draw lines to the point of distance, cutting B D′ in H′ and J′.

From H′ draw a horizontal line, cutting G G′ in G″, and cutting F F′ in I and C′ E in C″. From J′ draw a horizontal line, cutting G G′ in K, and F F′ in L and C′ E in M.

It will then be seen that at the corners of the original area the plans of the four feet are delineated—viz., C′ F I C″, G B H′ G″, M L F′ E, K J′ D′ G′, and a complete ground-plan of the table is thus put into perspective. Now proceed with projecting the table itself, in the following manner :—

At C′ and B erect perpendiculars, make these the required height of the surface of the table, and draw the horizontal N O.

From N and O draw lines to the centre of the picture.

Draw a perpendicular at D′, meeting O C in P. Draw the horizontal P Q, which will complete the block of the table.

Draw the horizontal R for the lower edge of the plate of the table, and from the point where it meets the perpendicular B O draw a line to the centre.

Now draw the perpendiculars F, G, H′, and J′, and the horizontal S, between F and G, for the framing of the table.

This framing is mortised into the legs, and therefore the line must not be drawn across the lines F and G, which represent the edges of the legs; but as it is necessary to find the correct position of this framing on the perspective side, produce S lightly to the angle T, and from T draw a line to the centre of the picture. Strengthen this line only between the points U and V.

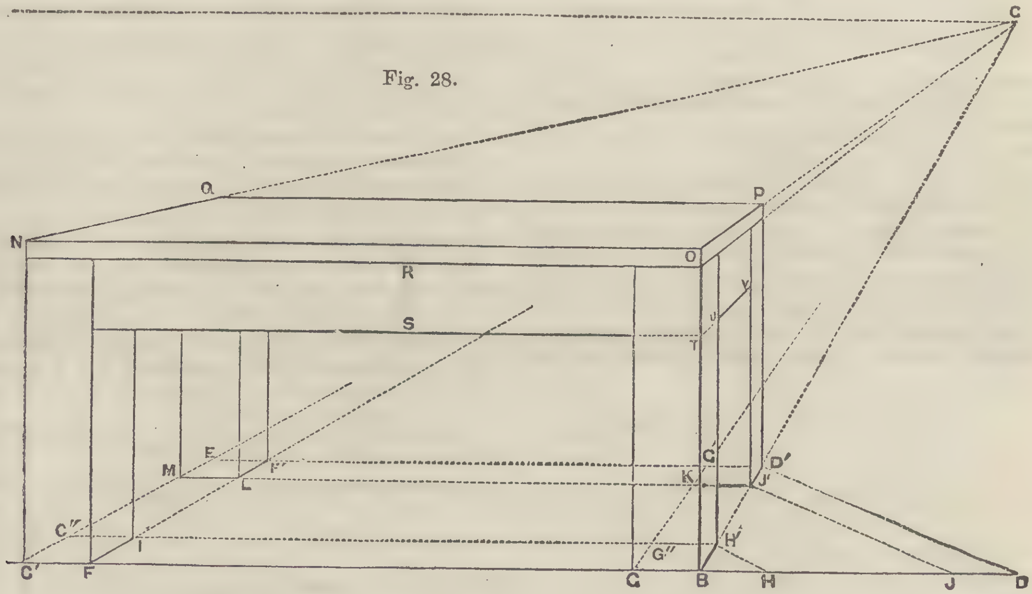
Strengthen that portion of the horizontal J′ K which lies between J′ and the perpendicular H′. It will be easy to understand that the inner edge of the distant leg of the table would rise from K, but in the present study this is hidden by the leg G B. The student is, however, recommended, when he has worked the present study, and understands the principles laid down, to change the position, for it will be evident that if the object were placed farther left, the point K would become visible. For the fourth leg, the upper part of which is hidden by the top of the table, draw perpendiculars from the points M, L, F′, and these will complete the object. The whole of the lines constituting the figure should now be thickened or inked.

Fig. 29.—This study is merely another view of the last subject, in which the end B O P D is parallel to the picture-plane.

The working of this will be carried on in precisely the same manner as the last, with this exception, that in starting, the points B, H, J, D are marked on the picture-line, and lines drawn from them to the centre of the picture. Then the points G, F, C′ are marked, and lines drawn to the points of distance, all of which is the reverse of what was done in the last figure; and thus it will be seen that the figure B D C′ E represents the plan of the table with its narrow end towards the spectator, whilst the long side is seen receding from the plane of the picture.

The lines and points are lettered to correspond with those in the last view, so that the change of position may be clearly traced. It is not necessary to repeat the working.

Fig. 28.



Exercise 14.

Scale, ½ inch to the foot. Height of the spectator, 6 feet; distance, 18 feet.

Put into perspective a cross made of stone 1½ foot square—total length of the upright, 12 feet; length of the arm, 7½ feet. The arm crosses the upright at 7½ feet from the bottom of the upright. Draw a plain elevation of this cross, and then project a perspective view when lying on the ground, at 3 feet on the left of the spectator, in such a manner that the end of the arm is parallel to the picture-plane, and is in the immediate foreground.

Exercise 15.

Put into perspective the same cross when lying on the ground, so that the lower end of the upright is parallel to the picture-plane and 6 feet within the picture; all other measurements at pleasure. By this term—frequently used in examination papers—is meant that the student may fix his own dimensions, so long as he shows that he understands the working out of the principle.

Exercise 16.

Scale, height, and distance of spectator at pleasure.

There are two blocks of stone, 2 feet square at their base, and 8 feet high. They stand 4 feet apart, and across the top of them rests a block, 8 feet long and 2 feet square at its ends—the faces of all three blocks being in one plane, that is, if a flat surface were placed against them, every part of the faces of all three blocks would touch it.

Put into perspective this object, when the plane of its face is parallel to the picture-plane, and when it stands at 8 feet on the left of the spectator and 10 feet within the picture.

EXERCISE 17.

Put into perspective the same object when standing so that its face is at right angles to the picture-plane, at 9 feet on the right of the spectator, and 6 feet within the picture.

EXERCISE 18.

The height of the spectator is 6 feet, his distance 18 feet, the scale being 1 inch to the foot.

Put into perspective the table which forms the subject of Figs. 28 and 29 when standing at 4 feet on the right of the spectator and 6 feet within the picture—the long side of the object to be parallel to the picture-plane. The dimensions of the table may be at pleasure.

EXERCISE 19.

Put into perspective the same object when its end is parallel to the picture-plane—at 7 feet on the left of the spectator, and 5 feet within the picture.

The object of the next study is to teach the method of making perspective projections of pyramids.

Fig. 30.—Let the length of the side of the base be represented by A B; then, as has already been shown, the perspective view of the plan will be the figures A B C″ D.

Now if the diagonals A C″ and B D be drawn, intersecting in E, it will be clear that the apex of the pyramid will be *somewhere* on the perpendicular raised on E.

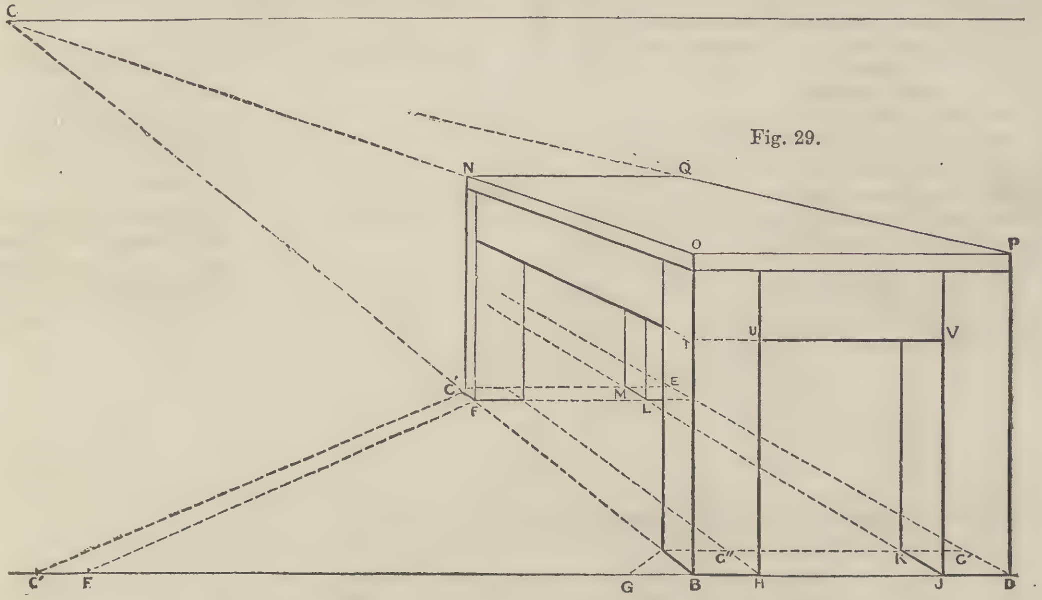


Fig. 29.

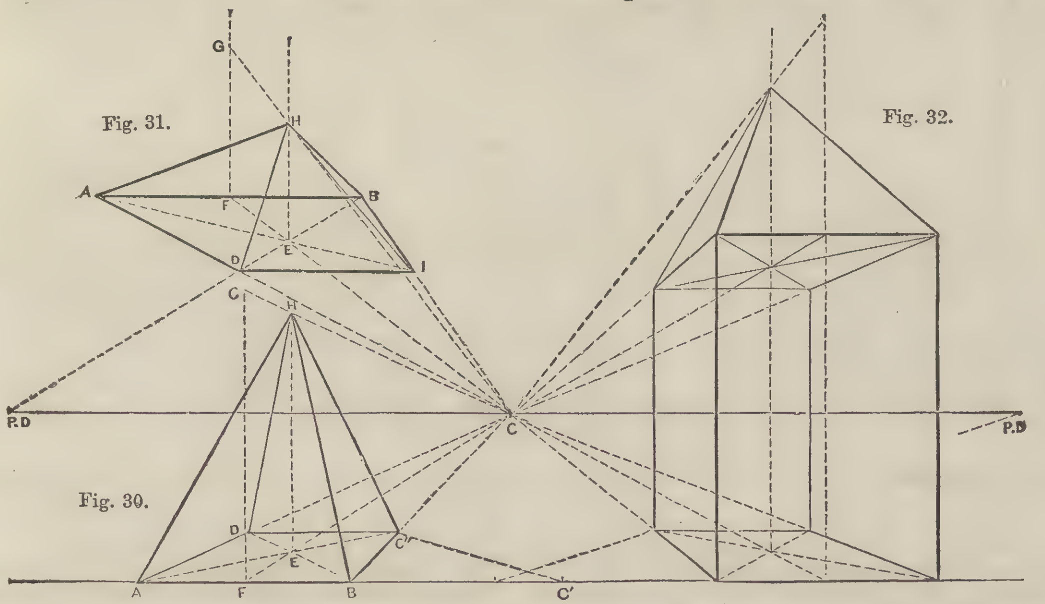


Fig. 31.

Fig. 32.

Fig. 30.

But this perpendicular lies within the picture, and therefore the *true* height of the pyramid will be somewhat diminished; therefore, draw a line from the centre of the picture, through E, and meeting the picture-line in F.

F is therefore E brought to the foreground, and a perpendicular raised in F will represent the perpendicular E when it has travelled in a track at right angles to the picture until it reaches the picture-line; and now these two lines are said to be in *one plane*, because if a wall extended from F to the centre of the picture, both these perpendiculars would be portions of the surface of such wall or plane; and thus a line drawn on the plane from any point in the perpendicular F, parallel to the base-line of the plane, would pass through the perpendicular E.

Now the plane supposed to stand on F C is at right angles to the picture; and therefore F is drawn to the centre of the picture, and a line drawn from any part of the perpendicular F parallel to the ground-line must also vanish in the centre of the picture.

Therefore, mark on the perpendicular F the real height of

the pyramid—viz., F G. From G draw a line to the centre of the picture, cutting the perpendicular E in H, which is the perspective position of the apex. From A, B, C″, and D draw lines to H, which will complete the figure.

Fig. 31 shows the perspective projection of a pyramid when higher than the level of the spectator. Here the length of the side of the base is A B, and from A and B lines are drawn to the centre of the picture. Then from B a line drawn to the point of distance gives D, the distant angle, and the horizontal D I completes the view from below of the base of the pyramid. In this there will thus already be one diagonal—viz., B D: draw the second, A I, intersecting B D in E, and at E erect a perpendicular. From the centre of the picture draw a line through E, meeting A B in F. At F draw a perpendicular, and on it mark the real altitude of the pyramid—viz., F G. From G draw a line to the centre of the picture, cutting the perpendicular E in H. Then H is the position of the apex. Draw lines from A, B, I, and D to H, which will complete the projection.

EXERCISE 20.

The height of the spectator is 6 feet, and his distance 15 feet. Scale, $\frac{1}{4}$ inch to the foot.

Put into perspective a pyramid, the base of which is 6 feet square, and the altitude of which is 8 feet. The pyramid stands at 5 feet on the right of the spectator.

EXERCISE 21.

Put into perspective the same pyramid when standing at 4 feet on the right of the spectator, and at 8 feet within the picture.

EXERCISE 22.

The same picture and the same horizontal line, etc., to be used.

Put into perspective a block, 9 feet high, and 4 feet square at base, with a pyramid 5 feet high resting on it, its edges corresponding with those of the upper end of the block. The object is to stand 5 feet on the left of the spectator.

Fig. 33.—In this figure the object represented is a structure consisting of four square piers supporting a pyramidical roof.

It will at once be seen that this is a further development of the

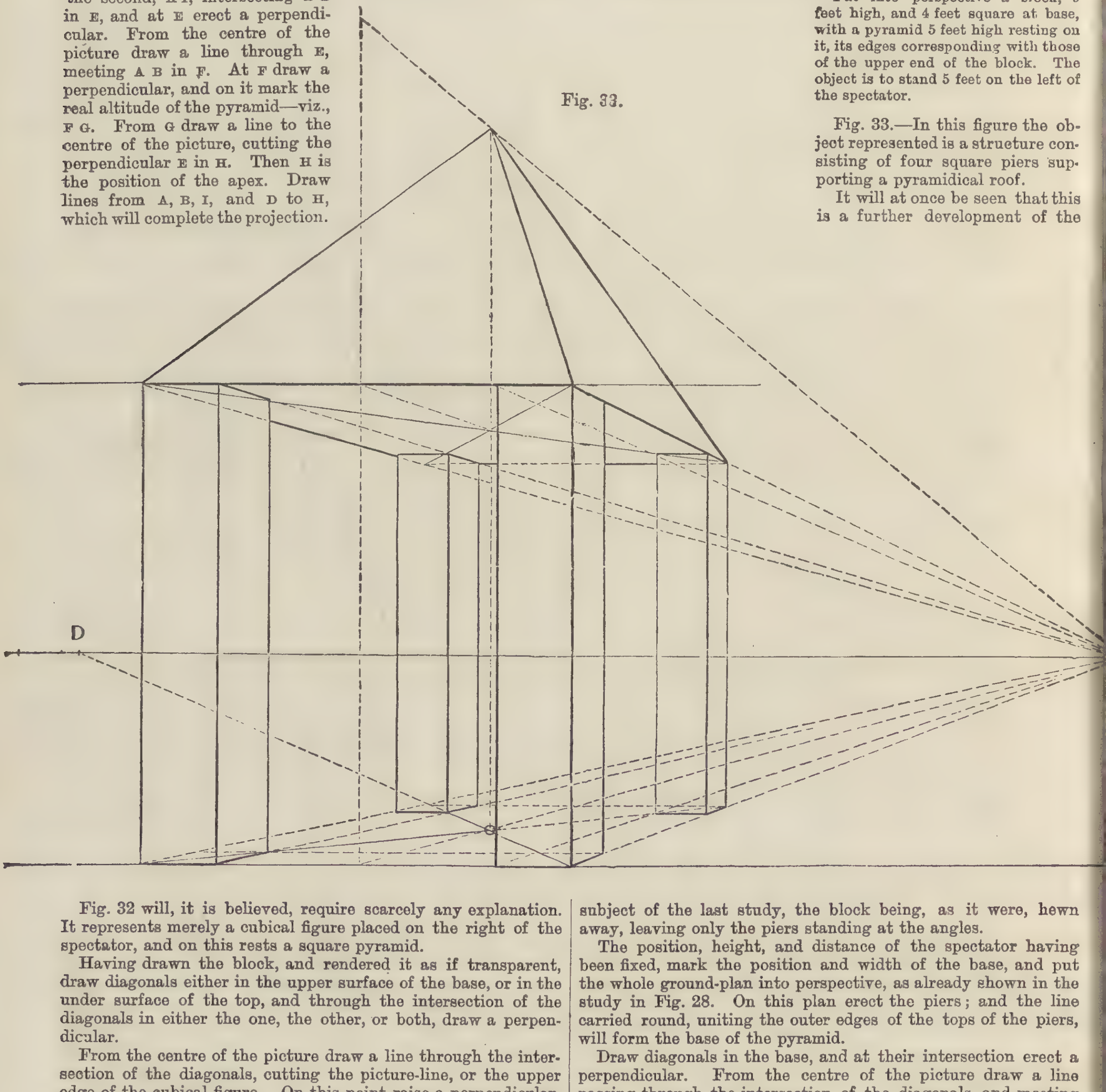


Fig. 33.

Fig. 32 will, it is believed, require scarcely any explanation. It represents merely a cubical figure placed on the right of the spectator, and on this rests a square pyramid.

Having drawn the block, and rendered it as if transparent, draw diagonals either in the upper surface of the base, or in the under surface of the top, and through the intersection of the diagonals in either the one, the other, or both, draw a perpendicular.

From the centre of the picture draw a line through the intersection of the diagonals, cutting the picture-line, or the upper edge of the cubical figure. On this point raise a perpendicular, and set off on it the real height of the pyramid above the block on which it stands.

From the point thus marked draw a line to the centre of the picture, which, cutting the perpendicular rising from the intersection of the diagonals, will give the perspective height of the pyramid.

subject of the last study, the block being, as it were, hewn away, leaving only the piers standing at the angles.

The position, height, and distance of the spectator having been fixed, mark the position and width of the base, and put the whole ground-plan into perspective, as already shown in the study in Fig. 28. On this plan erect the piers; and the line carried round, uniting the outer edges of the tops of the piers, will form the base of the pyramid.

Draw diagonals in the base, and at their intersection erect a perpendicular. From the centre of the picture draw a line passing through the intersection of the diagonals, and meeting the edge of the base of the pyramid. At this point draw a perpendicular equal to the altitude of the pyramid, and from its extremity draw a line to the centre of the picture, cutting the distant perpendicular in a point, which will be the apex of the pyramid. To this point draw lines from the angles, and these will complete the projection.

MINING AND QUARRYING.—II.

By George Gladstone, F.C.S.

COAL.

IMPORTANCE OF COAL—ANNUAL CONSUMPTION—EXTENT OF SUPPLY—GEOGRAPHICAL DISTRIBUTION.

Coal is so essential in all mining and metallurgical processes, that it fitly takes the first place in the present series of articles. Fuel of one sort or another is of course to be found in every country under heaven; but fuel of a sufficient heating power, and at a comparatively reasonable price, is one of the most important elements in the prosperity of a nation.

Great Britain is singularly blest in this respect. The supplies are large. Some people may, perhaps, be disposed to think that this is not altogether an unmixed good; for (whether fortunately or not to succeeding generations) the extent of the supply, and the convenient situation of many of the coal-fields to ports of shipment, naturally encourage exportation on a large scale to foreign parts. Both the home consumption and the export have indeed increased of late years with such rapid strides, that alarmists have been raising the cry of the early exhaustion of our coal-fields.

This led to serious inquiry into the matter, and very different opinions were arrived at by those best qualified to judge. One geologist, writing in 1861, estimated the total available supply of the British coal-fields at 79,843,000,000 tons, which at the rate of consumption of 1859—viz., 72,000,000 tons—would make it last 1,100 years. But the writer did not shut his eyes to the fact that the annual consumption was increasing at a rapid ratio, and he accordingly allowed in his calculations for an annual increase of 1,500,000 tons. The effect of this allowance was to reduce the 1,100 down to only 325 years!

The increase of 1,500,000 per annum was based upon the statistics of the previous five years; but in 1867 the production was no less than 104,500,000 tons, representing an increase between 1859 and the latter date of no less than 4,500,000 tons per annum. In the face of such astounding facts as these, it seems almost futile to attempt an estimate of the probable duration of our coal-fields. One thing is certain, that every right-minded person must hail with gratitude every invention of modern science which tends to economise the consumption of fuel.

The elements that have to be considered in the calculation of the available supply are rather numerous. 1. The depth to which workings can be carried. 2. The thickness of workable coal in the various coal-fields. 3. Their area. 4. The extent to which they are already exhausted. 5. The probability of extending their area, or of opening up new fields.

1. In the previous paper it has been shown that in consequence of the natural increase of temperature a mine will be sufficiently hot (viz. 80°) at a depth of 1,750 feet. But in order to get an available supply of 79,000,000,000 tons, it is calculated that coal-mining will have to be carried to a depth of 4,000 feet. This, of course, would be impossible without artificial contrivances; but, however shallow a coal mine may be, the ventilation must be attended to for the purpose of carrying off the dangerous gases. The means of ventilation are therefore well understood by miners, and its effect in cooling the air of mines is well known; so that with such improvements as may be made in the course of years, we may fairly take 4,000 feet as a reasonable limit. Some persons anticipate the possibility of going down 5,000 feet, but the former figure will be adopted here.

A very complete and careful series of observations on the increase of temperature was made years ago at Dunkinfield Colliery (Cheshire), which favours the supporters of the lower level, as it was then found that the rate of increase was only equal to 1° Fahrenheit for every 84 feet from surface. The temperature at the great depth of 2,055 feet was only 75·5° F. It may be that some local circumstance favours the miner in this particular colliery; for it is not altogether borne out by similar investigations in other collieries, though they seem to indicate that the rate of progression in coal mines is scarcely so rapid as in others. At Wigan a temperature of 80° was recorded at a depth of 1,800 feet, and at Monkwearmouth a similar rate of augmentation has been registered—viz., 1° F. to every 60 feet. It is not unreasonable to suppose that considerable differences in temperature may be due to the nature of the rocks through which the shaft passes, so that it may hardly be right to compare a colliery in this respect with a Cornish tin mine; and for our present purpose we may fairly take 1° in 60 feet as our datum.

2. The thickness of workable coal in any coal-field is also, to some extent, a matter of opinion. It would be a simple affair if the coal were all in one seam, but that is not the order of Nature. In some coal-fields there are twenty seams or more; it rarely happens that there are less than four or five. There is no regular rule that can be laid down as to the limit in respect of thickness at which a seam of coal ceases to be workable. In some parts of the country much thinner seams are worked than at others; and there can be no doubt that an important increase in the value of coal would lead to the working of many thin seams which are now altogether neglected. Those only two feet thick have been worked before now in some districts, and probably the time will come when all such seams will be made use of, though on economical grounds that will not take place until the thicker seams are well nigh exhausted. Some seams, moreover, are very liable to change in this respect, so that the thickness observed in one working is no criterion for others even in the same neighbourhood. In Fig. 5, which represents the lower levels of the Baremoor Colliery, in the South Staffordshire coal-field, an illustration is afforded of the great changes which occur in what is known there as the "thick coal."

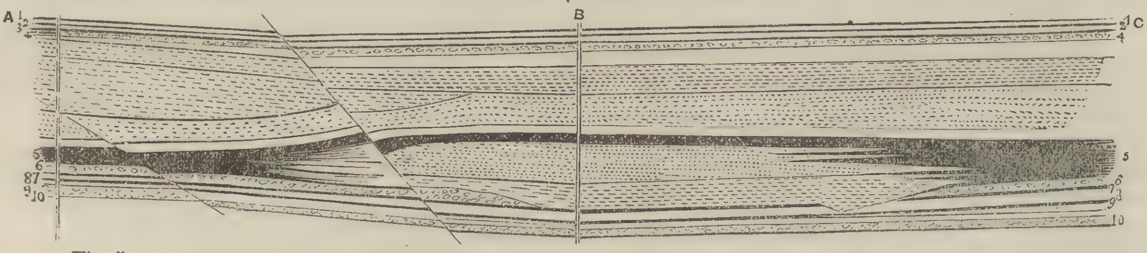


Fig. 5.—Lower levels of the Baremoor Colliery, South Staffordshire. Scale, 1 inch = 176 feet.
1, the two-foot coal; 2, the Broach coal; 3, the Herring coal; 4, the Broach binds ironstones; 5, the thick coal; 6, the Grains and Gubbin ironstone; 7, the first Heathen coal; 8, black batt and fire-clay; 9, the second Heathen coal; 10, cake and white ironstones.

In the old pit marked A, the seam is 31 feet thick; at the new one, B, only 9 feet; while at the other end of the diagram, C, it is seen to be still thicker than at A. This cannot but be regarded as an extreme instance, for it is the thickest known seam in the British isles; but it is no uncommon thing for one that is well worth working in one pit, to thin off so much as to be of no commercial value whatever in a neighbouring colliery. Until, therefore, every seam has been thoroughly explored throughout all the coal-fields of Britain, this element of uncertainty must attach to all calculations.

3. The area of the coal-fields may be taken at about 4,500 square miles; but in many places coal is now worked beyond these limits, being overlaid by more recent strata; and if a depth of 4,000 feet be realised in practice, 1,000 square miles will probably have to be added to the previous figure.

4. The operations at some of the coal-fields are yet almost in their infancy, while others have seen their best days. Formerly the workings were carried on with less system and more wastefully than now, and some of those in the iron districts, such as the neighbourhood of Birmingham and Coalbrook Dale, have suffered very considerable exhaustion. Even in these there is still a large quantity of coal which can be saved by

judicious working. It will be evident, however, that in forming any estimate of the quantities remaining, each coal-field must be separately considered.

5. As to the probability of extending their area, and of opening up new fields, a considerable difference of opinion exists. This point can only be determined by actual borings. It has been found within the last few years that the superior strata in some parts of the midland counties are not so thick as had been supposed, and that the Carboniferous rocks are within a practicable depth. Nor is there any substantial reason why the workings should not be carried some little distance under the sea.

Adopting, then, the data furnished by the Geological Survey, and taking only those seams which are 2 feet thick and upwards, and which do not exceed 4,000 feet in depth, Mr. Hull arrived at the calculation that 79,843,000,000 tons of coal still remained available. Since he made his estimate, however, the odd 843,000,000 have been consumed.

The various coal-fields lie in patches extending from Gloucestershire and South Wales up to the extreme north of England; and in Scotland on both sides of the Forth and Clyde, and in Ayrshire. In Ireland there is a wide extent of Carboniferous rocks, but the beds of coal are very uncertain, and are only worked to a very small extent.

The South Wales coal-field covers an area of about 900 square miles, and the quantity of produce may be taken at about 16,000,000,000 tons. Its commercial value is considerably enhanced by its geographical position, having the Bristol Channel for its southern boundary, and by the fact of the coal seams being interstratified with bands of ironstone. The facilities for shipment of the coal at Swansea, Cardiff, Newport, and other ports, have led to a very large export trade; and the presence of iron ores in such abundance has created an immense demand for coal in the smelting and puddling works, and rolling mills. A peculiar feature of this coal-field is that the character of the coal materially alters as you proceed downwards, and from east to west. The seams at the eastern extremity are more or less bituminous, the upper being more so than the lower; in the middle of the coal-field they are semi-bituminous and anthracitic (the latter lowermost); and in the extreme west there is none but anthracite.

The Yorkshire and Derbyshire coal-field, extending continuously from Leeds through Sheffield, and nearly to Derby, is, including the coal-ground overlaid by more recent formations, more extensive than the preceding, and will yield at least as much coal. The produce of this great inland district is almost entirely consumed at home. In this region some very excellent iron ores are obtained, from which the best iron in the kingdom is made. The coal underlying the Permian and Triassic rocks on the eastern side of this coal-field has been worked as yet to only a very small extent.

The Newcastle field supplied London almost exclusively before the time of railways, the coal since brought to London by rail being principally raised in the midland counties. A very large quantity is exported to foreign parts, owing to the facilities of shipment at Newcastle, Sunderland, Hartlepool, and other ports. Both in area and in produce this is decidedly less than either of the two preceding, though about the double of any of the rest in England and Wales. It contains several valuable seams, each having its special advantages. One produces a strong semi-bituminous coal, very suitable for furnaces; another, the best quality of household coal; a third, a good gas coal, yielding also a very excellent coke. There is still some 7,000,000,000 tons of coal available in this district, though it has been worked for a very long period. It is traversed by a great whin dyke, which crosses the country in an east and west direction, on a line with the Tyne valley, by which the strata on the south side of the dyke are thrown down no less than 540 feet; the eastern end of this dyke may be seen to advantage at Tynemouth, where it juts out into the sea immediately on the north side of the harbour. Contrary to the rule which prevails so generally in other parts of the country, there is but little ironstone to be obtained in this coal-field.

The South Lancashire is the next in respect to size, and contains a very great thickness of workable coal; but it is troubled with numerous faults on a large scale. At Wigan, the cannel, which is very valuable for gas works, is three feet thick; but it gradually thins off in every direction from that point.

The South Staffordshire has already been mentioned as illustrative of the irregularity in the thickness of some seams. What goes by the name of the thick, or ten-yard coal, is, in fact, about a dozen different seams all united together. It generally runs about 30 feet thick; but at Foxyard's Colliery, near Dudley, it measures $39\frac{1}{2}$ feet, including six thin partings of shale, the solid coal being equal to $36\frac{1}{2}$ feet. At this spot, owing to considerable upheavings of the strata, the coal crops out at the surface, and for about 100 yards in length it is worked as an open quarry, with a face of 40 feet in height. It is the only instance in this country of an open coal-working upon such a scale. This is in the centre of the "Black Country," properly so called, a district almost wholly given up to the coal and iron trades. The consumption of coal at the iron works is now so great that, notwithstanding such a seam as this, the process of exhaustion is going on very rapidly, and there is scarcely 1,000,000,000 tons now left available in this field. There is one seam here which bears the inelegant but appropriate name of "stinking coal;" it is altogether neglected, as it contains so much sulphur that the fumes from it, if used for domestic purposes, would be intolerable, and it is absolutely useless for making iron, a very small admixture of sulphur being most injurious to this metal.

The less important coal-fields do not require separate notice. They are the North Staffordshire, the Bristol, the Forest of Dean, the Denbighshire, the Flintshire (which contains some very good cannel coal), and a few others.

The Scotch are important in more respects than one. The Clyde and Ayrshire fields actually join at some points, and they are one in their principal features. They furnish a strong slow-burning "splint" coal, which is associated with the celebrated black band ironstones, the splint being very suitable for the operations of the smelter. The notorious Boghead cannel also occurs in limited portions of this field; it is the best cannel in the whole kingdom, and is highly valued, though the seam only averages about $1\frac{1}{2}$ feet thick.

The Leshmahago coal basin lies a little further to the south. It is of limited area, but is likewise rich in cannel of very excellent quality.

The total area of the Scotch coal-fields exceeds 1,700 square miles, and the available produce may be estimated at about 25,000,000,000 tons.

In Ireland Carboniferous rocks occur; but the coal is of no great value, and it is only worked to a small extent. The available quantity is too doubtful to justify its being included in the general total. At Kilkenny anthracite is the staple article.

SEATS OF INDUSTRY.—IX.

BY WILLIAM WATT WEBSTER.

MULHAUSEN.

Few manufacturing towns on the Continent of Europe have acquired a wider celebrity, or are better entitled to a place in a series of papers devoted to the description of the chief representative seats of industry, than the enterprising little town of Mülhausen, or Mulhouse, which was recently transferred from France to Germany, along with the province of Alsace and the German-speaking portion of Lorraine. For many years Mülhausen has taken rank as one of the principal centres of cotton manufacture in France, and its name has been associated with a variety of schemes for the amelioration of the condition of the working classes.

Mülhausen is situated in a fertile and well-watered district about sixty-one miles S.S.W. of Strasburg, and twenty-seven miles south of Colmar. It is divided into two parts, called old and new Mülhausen. The old town is built on an irregular oval-shaped island formed by the river Ill, which at this point separates into several branches, and is crossed by four bridges. The houses are substantial, and the streets are well paved and cleanly kept, although winding and rather narrow. Among the principal buildings in old Mülhausen may be mentioned the Reformed and Roman Catholic Churches, the Hôtel de Ville, and the College. The new town lies to the south-east of the old town, and extends from the right bank of the Ill to the Rhone and Rhine canal, which here expands into a spacious basin. It is laid out in wide, regular streets, lined with a superior class of houses. Mülhausen is an important station

on the Strasburg and Basle Railway. The list of the institutions established in the new town includes a Tribunal of Commerce, a Consulting Chamber of Manufactures, a Conseil de Prud'hommes, an Industrial Society, and a Commercial College. In 1855 the population of Mülhausen numbered 28,715, and it is now estimated at about 45,000, the last census having shown that it contained 43,244 inhabitants. Lambert, the celebrated mathematician, was born in Mülhausen, and in the centre of one of the squares of the town which bears his name, a large column has been erected to his memory.

The leading facts in what may be called the political history of the town, so far as they have been handed down to us, may be told in a few words. Mülhausen is said to have been known to the Romans under the name *Ariabinum;* but our knowledge of the place at that remote period is confined to the mere name, and long centuries subsequently elapsed of which we have no record. It is, however, certain that Mülhausen was a considerable town in the thirteenth century, for it was erected into a free and imperial city by Rudolph of Hapsburg in 1273. The next event in the history of Mülhausen that merits notice was the adoption of the Reformed faith by the authorities and inhabitants of the town in the year 1523. For several centuries previous to 1798, Mülhausen was the capital of a small republic belonging to the Swiss Confederation; but in that year it withdrew from the Federation, and, renouncing its independence, became incorporated with France, and its connection with that country continued up to 1871.

The manufactures of Mülhausen were of little importance till after the middle of the last century and the introduction of cotton-printing and muslin fabrics, which took place about the year 1745. Prior to that date the manufacture of woollen goods was almost the only industry of the place. But the progress of cotton manufactures in the town was very rapid, and the cotton-prints and muslins of Mülhausen soon became noted for the pre-eminent excellence and unrivalled variety of their colours and patterns. In these respects the productions of the looms of Mülhausen challenge comparison even with the silk goods of Lyons; and not a little of the prosperity which this town has so long enjoyed must be ascribed to the artistic merits of its fabrics. In the numerous mills and factories established at Mülhausen and its neighbourhood, there are, however, a variety of goods manufactured besides those we have mentioned. The silks woven there, and especially the flowered silks, are held in the highest estimation. A very superior quality of woollen and fine cambric goods is also manufactured in large quantities, and there are very extensive mills for the production of cotton and woollen stockings. Mülhausen has besides a reputation for damask and other linens, carpets, straw hats, stained paper, starch, parchment, chemical products, and the common qualities of leather, as well as morocco. Large iron-works have long been in operation in the town and vicinity, and locomotives and other descriptions of steam-engines are constructed in great numbers. The tanneries, bleach-fields, and dye-works of Mülhausen are very extensive, and its breweries and distilleries are held in high repute. There is a brisk trade carried on at Mülhausen, not only in the multifarious articles manufactured in the district, but also in raw cotton, wine, brandy, corn, and other agricultural products. The cotton manufactures of Mülhausen were very injuriously affected by the American Civil War of 1861-5, and it is to be feared that they have sustained another severe stroke by the events that have taken place in France since the 3rd of August, 1870. Before the Franco-Prussian war, however, the activity of the spinning-mills at this town had sensibly declined. The manufacturers of Mülhausen labour under the disadvantage of having to import their cotton by way of Havre or Marseilles, and the development of manufacturing enterprise in towns nearer the sea-board will doubtless tend to check, and may even eventually destroy, a large portion of the manufactures of the place. There are as yet few symptoms of decline. The manufacturers of Mülhausen have branch establishments in several parts of the Haut-Rhin and in the neighbouring departments, and till quite recently at least the amount of goods manufactured and exported was on the increase. A considerable proportion of the capital invested in manufacturing enterprise in Alsace is derived from Switzerland, and it is said that many of the mills and factories are heavily mortgaged to residents in Basle.

The work-people of Mülhausen did not always possess the many privileges they at present enjoy. About forty years ago the *Société Industrielle,* a body distinguished for its intelligence and patriotism, such as few manufacturing towns could boast of, drew up the following account of the state of the operatives in Alsace :—" They are allowed a quarter of an hour for breakfast and an hour for dinner, working for the most part from five o'clock in the morning till eight o'clock at night. Each family sleeps together in one room, which is either a cellar or a garret of the smallest dimensions. Their furniture is wretched, often only a miserable shake-down bed to accommodate all the family. They are very ill-clothed, often need the aid of the *Société de bienfaisance,* and are very dirty, especially in the spinning-mills. In the workshops obscene language and stories are often to be heard, which the children pick up with wonderful avidity, and repeat with a revolting zest." The next two sentences of the Société's report need not be translated. "Beaucoup des ouvriers," it continues, "vivent en concubinage. Ils appellent ces sortes d'unions *mariages à la Parisienne,* et en ont fait un verb allemand *parisiren.*" In 1835 Mr. Andrew Ure, the author of the "Philosophy of Cotton Manufacture," visited Alsace while on a tour through the cotton factories of France and Belgium, and has left us an account of his observations and reflections, from which we shall make a few extracts. "Great misapprehensions," he remarked, "prevail concerning the physical and moral condition of the factory operatives abroad, especially in the fertile region of Alsace. They have been represented as being mostly Protestants, and in very comfortable circumstances. There can be no greater mistake. Among the multitude of factory proprietors in Alsace there is only one Protestant. The working classes are devotees of the Romish communion." A little further on in the same work occurs the following passage on the condition of the Mülhausen operatives :—"If Sunday be a day of rest and tranquil pleasure to those who work in a moderate manner through the week, it is, on the contrary, a day of debauchery and orgies to those who, having been kept at labour beyond all reasonable bounds, take that occasion to riot in their liberty. Hence it is not uncommon here to see drunkards of from twelve to fifteen years of age. Their degree of instruction is very slender. All their physical, and in consequence all their intellectual, faculties are exhausted by toil. . . Certain enlightened proprietors have established, at their own expense, schools within their mills at Mülhausen, and especially M. Naegely. The cruel conduct of parents in sending their children at an almost infantine age to the factory, seldom fails to entail fearful retribution; for whenever the children discover the mercenary bargains of which they have been made the victims, they take the first opportunity of renouncing their filial engagements, and of abandoning their parents. And this alienation in the family, aggravated often by the brutality and ignorance of its head, is one of the main causes of the misery which prevails among multitudes of the work-people. The operative spinners of Mülhausen are generally pale, and subject to chronic catarrhs, which degenerate often into phthisis. The piecers and card-tenters sometimes lose the first joint of their fingers. The weavers are often seized with chronic rheumatism."

Such was the moral and physical condition of the vast majority of the factory operatives in Alsace at the time when Mr. Ure visited them; but several of the mill proprietors in that district had already began to show consideration for the welfare of their work-people. It is pleasant to turn from the dark picture suggested by, rather than delineated in, these extracts, to another passage in Mr. Ure's notes of his tour, descriptive of the great manufacturing establishment of Messrs. Gros, Divillier, Roman and Co., at Wesserling, in one of the most beautiful valleys of the Vosges mountains. This is pronounced by Mr. Ure to be "the most picturesque, peaceful, and well-ordered manufactory" he had ever seen, and he waxes quite eloquent in its praise. With the word-painting and the landscape we are not at present concerned, and so we shall pass at once to the substantial and economical portions of Mr. Ure's narrative. "The works of Wesserling," he tells us, "consist of cotton mills, power and hand weaving of calicoes and muslins, bleaching grounds, and print-works. The calico-printing was commenced as far back as the year 1760. The spinning mill, the loom shops, the bleach fields, and cylinder

press rooms date from the year 1802. The establishment is placed at a distance of two leagues from all towns, and is the central point of nine villages, containing a population of from 12,000 to 14,000 souls. There is no other manufactory within a league of it. Feelings of philanthropy presided at the origin of Wesserling. The first founders had for one of their objects to give comfortable employment to the natives of the valley, and they have been rewarded by an invincible attachment on the part of their work-people. Most of them (the operatives) are proprietors of a house and a little land, which their families cultivate, and the whole of them have rights to the use of the pasture-common. Their chief agriculture is that of the potato and meadow-grounds, and they all possess cattle. They are Roman Catholics, while their masters are Protestants of the Genevese church; but both live in the mutual charities of religion. The language of the country is still German as of old, and the temperament of the people is a little phlegmatic but docile. Their intelligence may be developed with a little pains, especially that of the female sex. The proprietors founded, sixteen years ago, a savings' bank for the operatives, which pays five per cent., and they study to persuade the youths to deposit. The work-people have benefit societies managed by themselves; but as the state of wages and employment seldom varies, they do not suffer from the vicissitudes of trade. A skilful medical man attached to the establishment attends gratuitously the workers and their families. Each of the villages has one or two well-conducted schools, and at Wesserling itself there is an upper school, erected by the public authorities as the model seminary of the canton."

It is within the last twenty years that the most successful efforts to improve the circumstances and character of the working classes of Mülhausen have been made. In the year 1853, the first Association for the erection of "cités ouvrières," or workmen's towns, was founded at Mülhausen, with a capital of 300,000 francs, in sixty shares of 5,000 francs, or £200 each. The State contributed 300,000 francs to assist the undertaking; the whole of which sum had to be laid out in streets, side-paths, sewers, fountains, plantations, baths, wash-houses, and bakeries. In order to convey an idea of the immense benefit this association has conferred on the community of Mülhausen, it may be stated that it has built about 700 houses, affording accommodation to a population of some 5,000. These houses are of various descriptions and dimensions, some consisting only of a ground-floor, while others have a storey. They are planned to meet the requirements of health, comfort, and decency; and each house has a garden attached to it. In a large number of cases, the working man is the proprietor of the house in which he resides. The method by which this is accomplished deserves to be detailed. A house with a ground-floor only costs 2,650 francs, or £106, and a house with an upper floor costs from 3,300 to 3,400 francs. The Association sells its house to the workman at cost price, and the purchaser begins by a payment of 300 francs, or £12, which is kept in reserve for the expenses of the contract, or is returned in the event of the purchaser being obliged to withdraw from the bargain, or unable to pay up the remainder of the price. When the last-mentioned contingency occurs, the Association repays to the purchaser the difference between his deposit and the claim it would have had against him if he had simply been a tenant. In all cases where a sale is agreed on, the purchaser is put in occupation, and by a payment of from 18 to 25 francs per month for a few years, according to the contract, he becomes the owner of the house. This monthly payment, it will be seen, is little more than an ordinary tenant would be charged as rent. When the Association merely lets its houses, it charges rent at the rate of 8 per cent. on the cost of the tenement; but the shareholders are bound by their charter not to take more than 4 per cent. interest on their money, and any surplus revenue that may be got pays for insurance, taxes, and repairs. The "cités ouvrières" of Mülhausen have proved so beneficial that the scheme has been adopted in Paris, and in other French towns. With the improvement in the material condition of the work-people of Alsace effected by Associations for the construction of workmen's towns and kindred movements, a corresponding moral advance has been made. But there is little of a distinctive character about the trade unions, co-operative and friendly societies of Mülhausen, and it is not necessary to describe them in the present article.

The Franco-German war was a critical period in the history of the town, and it is to be hoped that the energy and enterprise which have so long distinguished its inhabitants will enable them to surmount the difficulties in which they were consequently involved.

BUILDING CONSTRUCTION.—XV.

OF ROOFS GENERALLY.

THE term *roof* seems derived from the Saxon word *hrof*, or, perhaps, a contraction of the German words *Hier-auf* (upon here), and, as is well known, means the cover or top of a building, generally consisting of two sloping sides, though occasionally of other figures.

The ancient Egyptians, Babylonians, Persians, as well as other Eastern nations, had their roofs quite flat. The Greeks appear to have been the first who made their roofs with a slant each way, from the middle to the edges. This was very gentle, the height from the ridge to the level of the walls not exceeding one-eighth or one-ninth of the span, as may be seen by many ancient temples now remaining. In Northern climates subject to heavy rains and falls of snow, the ridge must be very considerably elevated. In most old buildings in Britain, the equilateral triangle seems to have been considered the standard both in private and public edifices, and this pitch continued for several centuries till the disuse of what is called Gothic architecture. The ridge was then made somewhat lower, the rafters being *three-fourths* of the breadth of the building. This was called the *true pitch;* but subsequently the half-square seems to have been considered the true pitch.

The heights of roofs were gradually depressed from the half square to one-third of the width, and from that to a fourth, which is now a very general standard, though they have even been executed much lower.

There are some advantages in high-pitched roofs, as they discharge the rain with greater facility; the snow continues a much shorter time on the surface; and they are less liable to be stripped by heavy winds.

Low roofs require large slates, and the utmost care in their execution; but they have the advantage of being much cheaper, since they require timbers which are shorter and of less scantling. When executed with judgment, the roof is one of the principal ties to a building, as it binds the exterior walls to the interior and to the partitions, which act like strong counterforts against them.

Roofs are of various forms, according to the nature of the plan, and the law of horizontal and vertical sections. The most simple form of a roof is that which has only one row of timbers arranged in an inclined plane, which throws the roof entirely on one side; this is called a "lean-to" or shed roof (Fig. 141).

The most general roof for an oblong building consists of two rectangular planes of equal breadth, equally inclined, and terminating in a line parallel to the horizon. Consequently, its form is that of a triangular prism, each side being equally inclined to the plane of the wall-head; this is generally called a "pent roof." Fig. 142 is the end view, or "gable," and Fig. 143 is the plan of such a roof.

When the plan is a trapezium, and the wall-heads properly levelled, the roof cannot be executed in plane surfaces, so as to terminate in a level ridge. The sides, therefore, instead of being planes, are made to wind in order to have the summit parallel to the horizon; but the most eligible method is to make the sides of the roof planes, enclosing a level space or flat, in the form of a triangle or trapezium, at the summit of the roof.

Roofs flat on the top are said to be *truncated.* These are chiefly employed with the view to diminish the height, so as not to predominate over that of the walls.

When all four sides of the roof are formed by inclined planes, it is called a "hipped roof" (Figs. 144 and 145), in which case two of the inclined sides—namely, those which slant from the long sides of the building—will be *trapezoids*, and the other two *triangles.*

But if the building to be covered be *square* (Figs. 146 and 147), and all the slides slant equally, the roof will form a square pyramid, for the projection and development of which see lessons in "Projection."

A building having a hipped roof consists of a square prism, on which a triangular prism rests, but the ends of the prism are slanted off.

When the planes of roofs, instead of being continued until they meet in a ridge, take another slant at a certain height, they are called "curb" or "Mansard" roofs (Fig. 148), from the name of their inventor, a great French architect* who lived in the sixteenth century. They are much employed in France, and are hence often called "French roofs." When the plan of the roof is a regular polygon, a circle, or an ellipse, the horizontal sections being all similar to the base, and the vertical section a portion of any curve, convex on the outside, the roof is called a *dome.*

We will now enter more particularly into the construction of a roof, in order to explain the principles which guide the designer, and to give the names of the different timbers employed.

It has already been stated that a badly-designed roof may prove the ruin of an entire building by forcing the walls outward; whereas, if constructed on correct principles, it will tend to tie them together, and so give firmness to the whole structure; and it has also been mentioned that the most generally adopted roof is that formed by two inclined planes; but it will at once be seen that this must be very limited in its application, and could only be used with anything like safety where the walls are very strong so as to resist the pressure of the roof; for it must be clear that the weight of the timbers and slates or tiles would tend to force the walls out of the perpendicular. This will be understood on referring to Fig. 149.

Now when this force (W) came into action, it would spread the feet of the rafters outward, and therefore the obvious remedy is to *tie* them together. Thus a *rope* would, to a certain extent, answer the purpose; but instead of tying the feet of the rafters together, they are mortised into a beam called the *tie-beam,* in such a manner that they cannot spread outward, and this is the first step towards the proper construction of a roof. Wall-plates have already been mentioned. They are timbers laid on the tops of the walls to prevent the roof-trusses pressing on one particular part, and to spread the pressure along the whole length. Resting on these, and crossing the entire width of the building, the long timber *tie-beam* is placed; and the very manner of placing it is such that any weight pressing on it may bear downward and not outward, and thus it ties the walls together; into this the rafters are mortised, in one or other of the methods already shown.

The rafters are not allowed simply to meet at the top, but abut against the slanting part of an upright, called the *king-post,* the purpose of which must not be misunderstood.

Casual observers might imagine that the king-post rests upon the tie-beam, and supports the rafters at their junction; but it does no such thing, the rafters abutting against the tie-beam meeting at the top and forming a triangle, because the two sides together are greater than the third ("Euclid," Book I. Prop. 20), and the third in this case is the tie-beam. Now, in the triangle A B C (Fig. 150), the weight D could be suspended; and as the two sides A and B meet in C, C becomes, as it were, the keystone of an arch, and firmly supports the weight D suspended from it.

Thus then, in Fig. 151, the points A and B act as the abutments of an arch, and the head of the king-post, K, is the keystone into which the upper ends of the principal rafters, P R, are mortised; and thus, the more the keystone be pressed down, the firmer will the structure be. But the weight of the roof does not really press upon the keystone, but upon the rafters, and these again transfer their force to the tie-beam, T B. Now, at its ends, the tie-beam is well supported, but in most cases is liable to sag, or sink in the middle; and if this were to occur, the ends of the rafters would be drawn inward, and with them the walls on which the wall-plates rest. The king-post is therefore a continuation of the keystone, and comes just down to, but does not rest upon, the tie-beam, which is therefore strapped up to the king-post by an iron band; and thus, instead of the tie-beam supporting the king-post, the king-post supports the tie-beam, the middle portion of which is suspended from it.

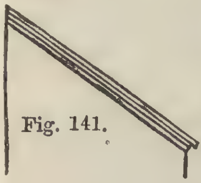


Fig. 141.

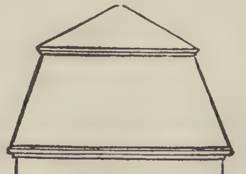


Fig. 148.


Fig. 147.

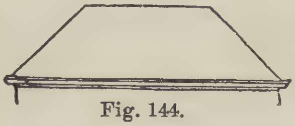


Fig. 144.


Fig. 142.


Fig. 146.

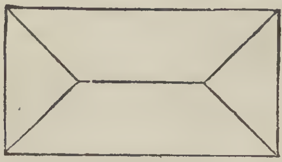


Fig. 145.

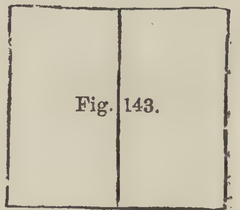


Fig. 143.

Fig. 149.

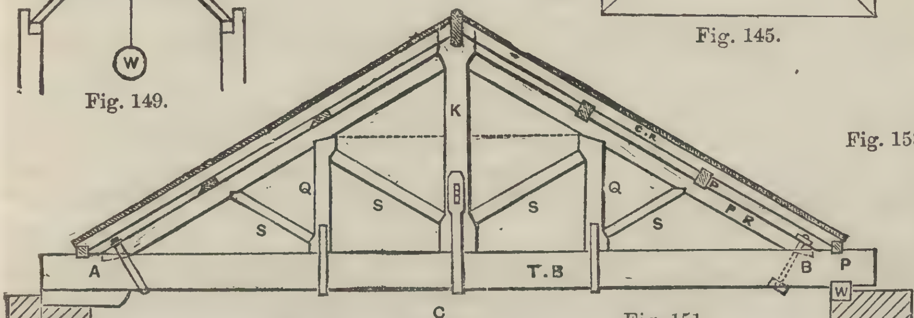


Fig. 151.

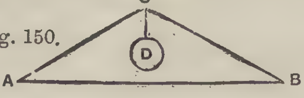


Fig. 150.


Fig. 153.

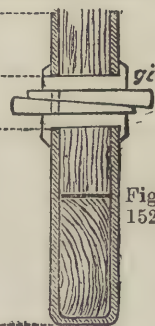


Fig. 152.

* Francis Mansard, an eminent French architect, born at Paris in 1598, was the son of the King's carpenter, and received those instructions which led to his eminence as an architect from Gautier; but for the high rank to which he attained in his profession he was indebted to the force of his own genius: he died in 1666. His nephew, Jules Hardouin, became a great favourite of Louis XIV., and was enabled under his patronage to realise a large fortune. Amongst his principal works were the Château de Clugny and the Palace of Versailles. He died suddenly at Marly in the year 1708.

In order to tighten up the tie-beam, an opening is pierced through the upper ends of the iron strap, and through the king-post. Iron "gibs" are passed through this hole, and two iron wedges entering from the opposite sides are driven in. It will be evident that the effect of this will be to draw up the strap, and with it the tie-beam around which it is placed. Fig. 152 is a section showing the king-post, tie-beam, iron strap, gibs, and wedges, and Fig. 153 shows the front of the strap.

All the parts referred to will be seen in their places in Fig. 151, in which are also shown struts, S, S, which, abutting on the foot of the king-post, support the principal rafters, P R, at a point between their upper and lower ends. If the width require that the beam should be further braced up, the struts S, S, then, instead of being mortised directly into the rafters, serve to support two posts smaller than the king-post, but of the same character, called *queen-posts*, Q. To these, again, the tie-beam is strapped up as in the former case. Against their feet struts abut, supporting the rafters; and it will be seen that this system may be carried on as long as the nature of the materials would permit; the whole truss resting on the wall-plates, W.

Now it will be clear that such strong and heavy assemblages of timber as these roof-trusses need not necessarily be placed close together, being intended as the main supports of the whole covering of the building; further framing is therefore necessary, in order that the intermediate spaces may be properly and securely roofed over. This is done by throwing timbers at intervals across the trusses. These are called "purlins," P, and are sometimes "notched" on the principal rafters, as at P, on the right side of the drawing, or rest against blocks, as shown at the corresponding point on the left side; the latter is to be preferred, as the principal is not weakened by the removal of any part of the thickness. Thus a horizontal framework is created, and across these, at about a foot apart, smaller timbers called "common" rafters are placed, C R. These either abut on a timber called the pole-plate, *p*, resting on the end of the tie-beam, outside the insertion of the foot of the principal rafters, or may be notched on to it, and passing by it, may form the eaves, or projecting part of the roof, under which a gutter may be placed. Across the common rafters strips of wood called "battens" are nailed, and to these the slates are attached; or, in cases where the inside of the roof is to be left visible, it is covered in with boards, to which the slates are nailed. The interior of these boards, and the timbers on which they rest, are then stained and varnished: and such roofs have a beautiful appearance, especially when the lines are such as to show the scientific principles upon which the whole is constructed. The open timber roof of the Middle Ages forms one of the most beautiful features of that period of architecture. They were, in the first instance, constructed on the most perfectly correct principles of science. They were then, in some cases, elaborately carved and filled in with most exquisite tracery, or were painted. The construction was not *concealed* by ornament; but, on the contrary, the decoration served all the more to show the construction to advantage. And we can thus feel the truth of Mr. Brandon's words: "A timber roof of the fifteenth century, with its massive timbers elaborately wrought; its rows of hammer-beams, terminating in beautifully-carved figures of angels; its enriched panelling and traceried spandrils; its exquisite bosses; and, above all, its profusely-ornamented cornice, is truly as glorious a sight, as it is a grand triumph of the carpenter's art. Such excellence, however, was but very gradually accomplished."*

In some cases the heads of the queen-posts are kept apart by a horizontal timber (shown by a dotted line in Fig. 151) called the *straining beam*, which is strapped up to the king-post, which in such a roof-truss would not come down to the tie-beam. The subject of roofs in timber and iron is of such importance, and its elucidation requires such numerous illustrations, that a separate series of lessons will be devoted to it in THE TECHNICAL EDUCATOR.

The leading principles of the construction of roofs covering a span of great width are exemplified in the complex structures by which our large railway stations and termini are covered in, and which may be studied with advantage.

* The whole subject of Gothic Architecture will be treated of hereafter in this work in a separate series of lessons.

VEGETABLE COMMERCIAL PRODUCTS.

XVII.

PLANTS PRODUCING VALUABLE GUMS, RESINS, AND BALSAMS (*continued*).

TURPENTINE PINE (*Pinus palustris*, Wild., and *Pinus Tæda*, L.; natural order, *Coniferæ*).—The importation of turpentine by other nations is not very considerable, since almost every country possesses trees from which it may be procured. England, however, is an exception, the demand for turpentine being much greater than the home supply. We receive nearly all our turpentine from the United States, and it is obtained from the above two species of *Pinus*. There are also in the market, Bordeaux turpentine, obtained from *Pinus pineaster*, Aiton; Strasburg turpentine, from *Abies pectinata*; Venice turpentine, from *Abies larix* (Rich.), the common larch; and Chio turpentine, from the *Pistacia terebinthus* (L.), a tree indigenous to Cyprus.

The process of collecting turpentine is in each case nearly the same. The bark of the trees being wounded, the turpentine trickles out in drops into boxes or other vessels placed so as to receive it. The incisions are made about the close of the month of March, and the turpentine continues to flow throughout the vegetative season, particularly during the summer months.

Turpentine is imported in barrels, weighing from two to two and a-half cwt., and has the appearance and consistence of honey. Oil or spirits of turpentine is obtained by distillation from the raw turpentine; this residue is the common resin or rosin of the shops. Spirits of turpentine, as a solvent of all resins, is much used in the preparation of paint and varnish; and rosin in the manufacture of common soap, common sealing-wax, for the bows of violins, and for caulking ships.

In 1863, 27,343 tons of turpentine, valued at £31,274, were imported into the United Kingdom, chiefly from North America.

GUM-ARABIC (*Acacia vera*, Wild., and *Acacia Arabica*, Wild.; natural order, *Leguminosæ*).—Gum-arabic is produced by these two trees, which grow in abundance in Arabia, and in Egypt on the banks of the Nile. It flows spontaneously from their trunks and branches, in the form of a mucilage, which dries and hardens on exposure to the air. The more sickly the tree, and the hotter the weather, the more abundantly exudes the gum. It is very nutritious, and the Arabs who gather it almost live upon it during the harvest.

The principal African and Arabian ports for the exportation of gum-arabic are Aden, Mokha, Suez, Cairo, and Alexandria. Gum-senegal, the product of *Acacia Senegal* (Wild.), is the best and dearest sort of Arabian gum. It is distinguishable from gum-arabic by its clearness, consisting of choice drops of tears, some as large as a pigeon's egg, entirely white, and shining like glass. Gum-tragacanth, which is yielded by *Astragalus tragacantha*, L., is also considerably in demand, and is one of the chief gums of commerce. We receive this gum from Greece and Asia Minor. The principal place for its exportation is Smyrna.

These gums are chiefly used in the manufacture of silks, crapes, and muslins, to stiffen and glaze the fabric; they are employed also in calico-printing, to give consistence to the colours; in medicine, painting, and in the manufacture of ink. The quantity imported in 1850 was 1,984 tons, of which 328 tons were gum-senegal.

GUM-SANDARACH (*Callitris quadrivalvis*, Verst.; natural order, *Coniferæ*).—This tree is a native of Barbary, on the African coast. The Turks construct the ceilings and floors of their mosques of its wood, which is all but indestructible. The gum, which is much used in making fine varnishes, is imported to the extent of from twelve to fifteen tons annually.

GAMBOGE (*Hebradendron gambogioides*, Grah.; natural order, *Clusiaceæ*).—Gamboge is a gum-resin obtained from this tree, which grows wild on the Malabar and Ceylon coasts. In Ceylon gamboge is obtained by wounding the bark of the tree as soon as the flowers begin to appear. It appears in commerce in three forms—in solid rolls or cylinders, in hollow rolls or pipes, and in amorphous masses or cakes. Gamboge is imported from Ceylon, Siam, and Cochin-China. The best is the pipe-gamboge from Siam.

Gamboge is employed as a water-colour or pigment by

artists, also in medicine as a drastic purgative. Our imports were—in 1863, 388 cwt., valued at £3,268; and in 1864, 42 cwt., valued at £520.

CAMPHOR TREE (*Laurus camphora*, L.; natural order, *Lauraceæ*).—The camphor tree is a native of China, Japan, Borneo, and the island of Formosa. Camphor—a gum-resin—is obtained as follows:—"The wood of the *Laurus* is cut into small pieces, and put, with plenty of water, into small iron boilers, which are covered with an earthen dome lined within with rice straw. As the water boils the camphor rises with the steam, and attaches itself as a sublimate to the stalks, under the form of granulations of a grey colour. In this state it is picked off the straw, and packed up for exportation to Europe." *

Camphor is brought to this country in chests, drums, and casks—in small granular, friable masses, of a dirty-white or greyish colour. It is much used in museums and private collections of natural history, as a preservative of animal and vegetable bodies against the depredations of insects. It is also used in medicine, in the composition of varnishes, and in the manufacture of fire-works. The total amount annually received from China and Japan is about 466,000 pounds.

FRANKINCENSE (*Boswellia serrata*, Roxburgh; natural order, *Amyridaceæ*).—This is an odoriferous gum-resin, much used by the Roman Catholics in their churches. It was employed by the priests of ancient Egypt to conceal the unpleasant emanations arising from the sacrifices offered in their temples. It is imported from India and the Levant.

ASAFŒTIDA (*Narthex asafœtida*, Falconer; natural order, *Umbelliferæ*).—This fetid gum-resin exudes from incisions made in the roots of the plant. It is first a milky juice, but when dried in the sun, acquires a mottled appearance and a pink colour. The plant is indigenous to the south of Persia, Affghanistan, and the Punjaub. Asafœtida usually comes over in casks and cases. It is much used in medicine as a valuable stimulant and anti-spasmodic, in cases of asthma and spasmodic cough.

VI. THE BARKS OF COMMERCE.

Many varieties of bark are known in commerce, the chief of which are those used for medicinal purposes, such as the Peruvian and Cascarilla barks; and economic barks, employed in the arts and manufactures, such as the bark of the cork oak, and the valuable tanning bark of the common oak.

MEDICINAL BARKS.

PERUVIAN BARK (*Cinchona Condaminea*, Humb. and Bonpl., etc.; natural order, *Cinchonaceæ*).—Peruvian bark is the product of various species of Cinchona, a group of evergreen trees and shrubs growing on the slopes of the Andes in Peru and Bolivia, at elevations varying from 7,000 to 10,000 feet above the level of the sea.

The medicinal properties of this bark are entirely owing to the presence of three alkaline and bitter principles—quinine, cinchonine, and quinidine—which are the most effective remedies known against intermittent and allied fevers. The Jesuit missionaries were the first to discover and make known its value as a remedial agent, and for a long time they were the sole vendors of it, whence its name of "Jesuit's Bark." The generic name *Cinchona* was given to the plant because, in 1638, the Countess of Cinchona, wife of the Viceroy of Peru, was cured of intermittent fever by its use; hence, also, the powdered bark was called *Pulvis Comitissæ*, or Countess's powder.

There are, at the fewest, twelve species of *Cinchona* from which the Peruvian bark of commerce is derived. All these resemble each other in their general features; having opposite leaves, which are shining, lanceolate, on short petioles, and small, tubular, and white or rose-coloured flowers, arranged in ample panicles at the extremities of the branches. The principal varieties of Peruvian bark recognised in the Pharmacopœia are the *pale*, the *yellow*, the *red*, and the *crown* bark. Pale or *grey* bark is obtained from *Cinchona nitida* and *C. micrantha*; Loxa or crown bark, from *C. Condaminea*; yellow or Calisaya bark is yielded by *Cinchona Calisaya*; the source of the red bark is not yet ascertained. The pale bark contains most cinchonine, the yellow most quinine; Loxa or crown bark, the largest proportion of quinidine; the red yields the alkaloids in about equal proportions.

* Ure's "Dictionary of Arts, Manufactures, and Mines." Vol. I. London, 1867.

Peruvian bark comes to us in the form of quills or hollow cylinders, which vary in length and diameter, the longest seldom exceeding two feet—the diameter varying from a quarter of an inch to two inches. These quills are the bark of the smaller branches of the tree, which rolls up thus as it dries in the sun. Pale black arrives in quills only; the Calisaya or yellow bark, and also the red bark, comes both in quills and flat pieces, which last are derived from the trunks, and reduced to this form by being alternately exposed to the sun and then subjected to pressure until perfectly dry. Peruvian bark is usually imported in packages, or *serons*, made of dried cow-hides. The annual imports into this country amount to between 80 and 90 tons. The cinchona plant has been introduced with every prospect of success into British India, where large plantations are now established in many of the hilly districts; and more recently into Japan and the Mauritius.

CASCARILLA BARK (*Croton Eleutheria*; natural order, *Euphorbiaceæ*).—This tree is a native of St. Domingo, the Antilles, and the Bahama Islands. Its bark is imported chiefly from Eleuthera, one of the Bahamas, and comes in small-sized quills and in chips. Cascarilla bark has strong aromatic and tonic properties, and is an excellent remedy in chills and fever, being occasionally employed as a substitute for cinchona. When burned it gives forth a sweet musky odour, and is often used in fumigations. The amount annually received in this country is from ten to twelve tons.

CEDRON (*Simaba cedron*, Aubl.; natural order, *Simarubaceæ*).—The cedron is a small tree confined to the republic of New Granada, ranging from about the 5th to the 10th degree of north latitude. Every part of the plant, but especially the seed—owing to the presence of an alkaloid (*cedrine*)—is intensely bitter. On account of this principle, it is used extensively, and with considerable success, in cases of intermittent fever. But the chief reputation of the cedron rests upon its being considered an efficacious antidote for the bites of snakes, scorpions, centipedes, and other noxious animals; and so highly do the natives of the land in which it grows value it, that they will pay a large price for a single seed.

QUASSIA AMARA, belonging to the same order as the cedron, is also a valuable febrifuge.

VII. TANNING MATERIALS.

In the bark of certain trees a peculiar light yellow glistening substance exists, called *tannin*, or tannic acid, which consists of small yellow crystals. This tannic acid has the power of combining with the gelatine in the skins of animals, and converting them into leather by forming a tannate of gelatine. The most valuable bark for this purpose is that of

OAK (*Quercus pedunculata*; natural order, *Cupuliferæ*).—Indigenous to this country, and also much cultivated. We import large quantities of oak bark from Holland and Belgium. In 1852 we received 19,034 tons, whilst the home produce was 150,000 tons.

VALONIA (*Quercus ægilops*).—Under this name the acorn-cups of this species of oak are used; although the tree is dwarf and shrubby, these cups are very large and much prized by tanners. Large quantities are imported from the Levant, chiefly *viâ* Smyrna, not less than 29,396 tons having been received in 1866. Sometimes the acorns are gathered before they are fully formed; they are then called *camata*, or *camatina*. In this state they are more valuable, but too expensive to be largely employed.

TECHNICAL DRAWING.—XXIX.

DRAWING FOR MACHINISTS.

ISOMETRICAL PROJECTION.

THE principles of isometrical projection having already been given in previous lessons (Vol. I., page 267), it is not necessary to repeat them here; it will be sufficient to remind the student that the square A C B D (Fig. 267) is represented in isometric projection by the lozenge A′ C *b* D.

From this figure it will be seen that the side D B of the square is at 45° to D E, whilst the side D *b* is at 30° to D E.

The difference, then, between the triangle D E *b* and the triangle D E B is the triangle D *b* B, the angle *b* D B being 15°, and D B *b* being 45°.

It will therefore be plain that if the side of a cube be given,

and we are required to find the side of the hexagon which would form the isometric projection of it, we need only take the length as the basis of a triangle, as D B, at the one end construct an angle of 30° (that is, an angle similar to B D *b*), and at the other an angle of 45° (similar to the angle *b* B D). This triangle then, as said before, will represent the side of the cube and its isometric projection.

The side D *b* of such triangle will be the required length of the side of the hexagon, and any divisions or parts marked on B D, as B *f*, may be transferred to *b* D by drawing a line from *f* parallel to B *b*, cutting *b* D in *g*; then *b g* will have the same proportion to *b* D that B *f* has to B D.

CONSTRUCTION OF AN ISOMETRICAL SCALE.

Although the method of constructing the isometrical scale has been given in a former lesson (Vol. I., page 269), it is repeated here for the convenience of the student, to save the trouble of reference to another volume.

Let it be required to construct an *isometrical scale* of $\frac{1}{12}$—that is, 1 inch to the foot.

Fig. 268.—Draw the line A B, and A C at an angle of 15° to it. It will be found convenient to draw an angle of 30° by means of your set-square, and to bisect this angle.

From A set off any convenient number of inches to represent feet, as A D, D E, dividing any one of them into 12 equal parts, as D E.

Now from E draw a line at 45°, cutting A C in F.

From all the points of division, 1 to 12, draw lines parallel to E F, and these will give on A C the divisions contained between G and F, which will represent the twelfths of inches in the isometrical measurement.

Fig. 269 is an isometric projection of a square case divided into compartments.

Let A be the position of the nearest angle of the object to be projected.

On each side of A draw a line with the set-square of 30° placed against the T-square. This will at once give the angle B A C (120°) which will be formed in the isometrical projection by the meeting of two lines at right angles to each other.

Now the measurements of this case are as follow:—General front elevation, 2′ 1″ square; depth, 5″; thickness of wood, 1″; width of compartments, 7″.

On A erect a perpendicular. Make A D and A B 2′ 1″ by the isometric scale. Draw D E parallel to A B, and B E parallel to A D. This will complete the isometrical projection of a vertical square, which would be the left side (A) of the cube shown in Fig. 270. From D and E draw lines parallel to A C. On A C set off the depth of the case—viz., 5″—and erect a perpendicular cutting the line drawn from D in F. From F draw a line parallel to D E, cutting the line drawn from E in G. This will complete the projection of the object treated as a block only.

Now it will be clear that, as the thickness of the wood is to be 1 inch, and there are to be three compartments in width, and three in height, these will be 7 inches each; therefore, along A B and A D, set off an inch for the thickness of the case, then a space for the compartment, an inch for the thickness of the board dividing the compartment, and so on.

From these points lines drawn parallel to the sides of the figure will complete the projection of the front of the case.

Now from each of the inner angles joining the planes of the sides of the compartments which would be visible, draw lines parallel to A C.

From the points on A D, marking the thickness of the shelves, draw lines parallel to A C, cutting C F in H, I, etc.

From these points draw lines parallel to A B; these, cutting the lines already drawn from the inner angles of the compartments, will give the distant inner angles at which the perpendiculars form the back edge of the upright divisions, and the projection will thus be completed.

Fig. 271 is the isometric projection of a *wooden stand for a machine.* It is drawn to the same scale as the last, $\frac{1}{12}$, the dimensions being as follow:—Length, 3 feet; breadth, 1′ 10½″; height, 2′ 5½″; thickness of legs and rail, 3″.

The lines A B (3 feet) and A C (1′ 10½″) having been drawn at the angle of 30° to a horizontal line, the lines B D and C D are to be drawn parallel to A C and A B respectively.

On each side of A, and inwardly from B and C, on the lines A B and B C, set off three inches representing the thickness of the legs—viz., E, F, G, and H.

From these points draw lines parallel to those already drawn, and these will complete the plan of the stand, giving not only the boundary lines of the space covered by the object, but also the projections of the square spaces in which the legs will stand; and this is one of the advantages of isometrical projection, in which the objects are worked without a separate plan or elevation, the drawing uniting in itself plan, elevation, and projected view.

It is not always necessary in practice to project the whole plan, but in the present case it is required in finding the inner sides of two legs, and the position and width of the distant one.

Thus the lines drawn from G and H, intersecting, give the point I, and being carried beyond this point they cut B D and C D in K and J, thus completing the plan of the distant leg.

Again, G J in passing through the line drawn from F gives the point L, whilst the line drawn from E, cutting H K, gives M, the position of the perpendicular for the inner side of the leg.

Now from A, B, and C erect perpendiculars.

Make A O 2′ 5½″ high, and from O draw lines parallel to A B and A C. These will cut the perpendiculars drawn from B and C in P and Q. The perpendiculars B P and C Q will necessarily be the same height as A O.

From P and Q draw lines parallel to O P and O Q, which intersecting in R will give the projection of the outline of the top of the object.

Draw perpendiculars from E, F, G, and H to meet the lines O P and O Q in S, T, U, V. From these points, lines drawn parallel to the sides of the external figure will give the projection of the top of the stand corresponding precisely with the plan.

From O set off O W, representing the depth of the upper rail —6″ by scale—and from W draw lines parallel to the sides of the object. The line drawn from W on the left side will cut the perpendicular H U in X, and similarly the line drawn from W on the right side will cut the perpendicular G V in Y.

Lines drawn from X and Y parallel to A B and A C will intersect in Z, and give the lower edge of the inner surface of the two distant rails.

The intersection Z will, if the work has been accurately done, fall on the perpendicular from I, the inner edge of the distant leg. Perpendiculars from J and K may now be drawn, and the cross-stay may also be added, thus completing the projection.

Fig. 272 is an isometrical projection of a simple *circular solid penetrated by a square prism*, showing the principles on which a wheel would be projected isometrically.

It will be remembered that projection does not deal with circles or curves as such, but requires that they shall be enclosed in rectilinear figures, across which diagonal or other lines are drawn. These figures are then projected, and the circles or curves are drawn through the points corresponding to those through which they would pass in the original figure.

Fig. 273 is a quarter of the circle about to be projected, enclosed in a square which would represent one quarter of the square required to contain the whole circle.

Now, as a rule, the thickness of the square solid to be projected would only require to correspond with that of the wheel; but in the present case the length of the penetrating prism or axle corresponds with the diameter of the circle, and the containing block would therefore be the cube A B C D E F G.

In the middle of the side A E the thickness of the wheel H I is to be marked, and the perpendiculars H J and I K having been drawn, the square slab which would contain the wheel is to be projected.

Now the whole square containing the circle would require that diagonals should be drawn across it; therefore in the square *j l m m′* (Fig. 273) draw the line *j m*, which would be the half diagonal. This small square, it will be remembered, is a quarter of the larger one, which for the present purpose is sufficient.

Draw diagonals in the surface projected from J H—viz., J H′, J′ H—which will represent the complete diagonals drawn across the square.

Through the point in Fig. 273, where the quadrant passes through the diagonal, draw a line to *n*; and from L in Fig. 272, which is the extremity of the horizontal diameter L L′, set off L N and L N′ equal to *l n* in Fig. 273.

From N and N′ draw lines parallel to A C, and these inter-

secting the diagonals, will give the points O, O, O, O, corresponding with o in Fig. 272.

Through the intersection of the diagonals draw the perpendicular M M′; then through the points L, O, M, O, L′, O, M′, O, L, draw the curve which will represent the circular face of the wheel.

Although this form is evidently correct, it is not a pleasant one, since the circle does not seem upright, owing to the longer diameter of the ellipse being on the diagonal drawn at H, instead of on the vertical diameter M′ M.

The difference of the results of the different modes of rendering the circle by projection will be clearly understood by referring to the speed-pulley projected from its plan, in lessons in "Projection," and by the circles, etc., projected in "Practical Perspective."

Still the advantages of isometrical projection are so many that the mere appearance is but secondary, as when pictorial views of machinery are required, or views of buildings or blocks of buildings, orthographic projection on the inclined plane, and perspective, can be employed.

Pictures of machines are, however, seldom required for trade purposes, and thus isometrical projection may truly be said to constitute the *perspective of the workshop*.

Proceeding now with our object, project from I K the surface I I′ K′ K, corresponding with H H′ J′ J; draw diagonals K I′ and K′ I, and through their intersection draw the diameters P p and q r.

Now it will be seen that these points P, p, q, r could have been obtained by drawing lines from L, M, L′, M′, as L P, M r, etc., and this knowledge enables us to find the points s, t, u by simply drawing lines from O, O, O, parallel to A E; these will cut the diagonals in the required points. The same result might be attained by drawing lines from N, N′ parallel to A E, to cut K I in V W, and from V W drawing lines parallel to A C, cutting the diagonals K I′ and I K′.

To project the square prism penetrating the wheel, set off

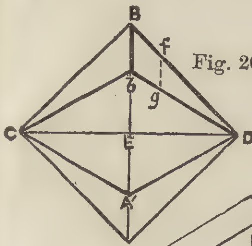


Fig. 267.

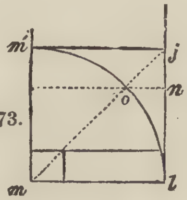


Fig. 273.

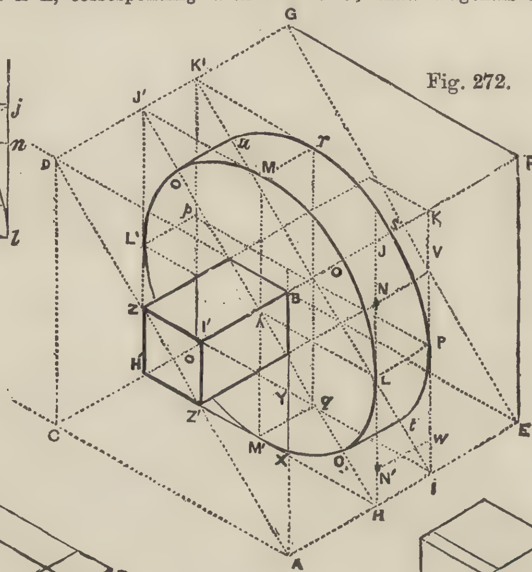


Fig. 272.

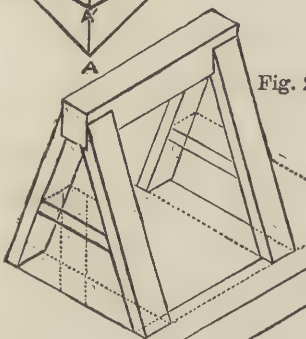


Fig. 274.

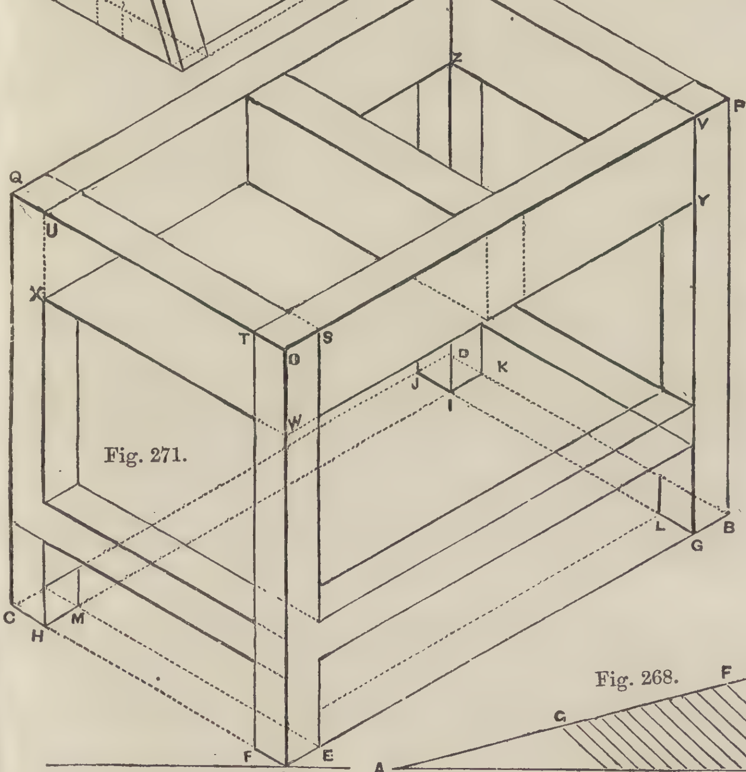


Fig. 271.

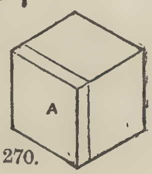


Fig. 270.

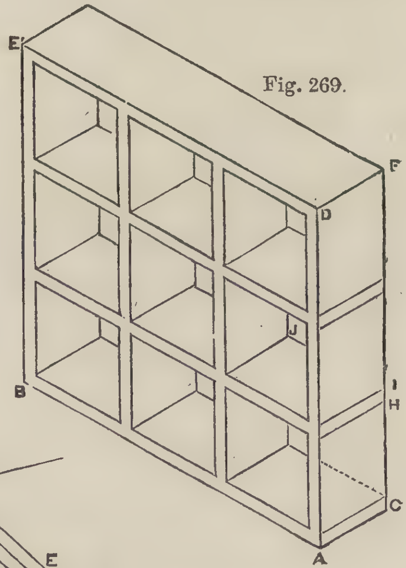


Fig. 269.

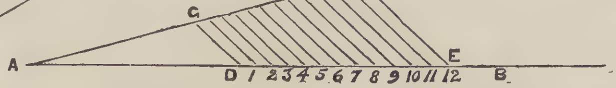


Fig. 268.

its width X Y on A B, and draw lines parallel to A C. These, cutting the diagonals A D, B C, will give the four points I′, Z, Z′, H′, which joined, will be the required projection.

It will be seen that the points I′ and H′ have already been used for a previous purpose. The points now used fall exactly on these; this would be altered if the prism were of a different length.

It will be evident that if the axle were required to be cylindrical, a circle could easily be projected in I′ Z′ H′ Z, as in the former portion of the figure.

The points at which the prism penetrates the wheel are found by drawing lines from I′, Z′, H′, Z parallel to A H, cutting the diagonals J H′, H J′, and its distant end is projected by producing these lines to cut the diagonals of the distant side of the cube.

Fig. 274 is an isometrical projection of a trestle, the working of which, being simply an application of principles already explained, is left to the knowledge and ingenuity of the student.

NOTABLE INVENTIONS AND INVENTORS.

XI.—THE COTTON MANUFACTURE.

BY JOHN TIMBS.

COTTON, named by the Arabs *Kutu* or *Kutun*, is a filamentous matter, produced from the surface of the seeds of the *Gossypium* plants, found wild in both the Old and New World. Herodotus and Arrian speak of the cotton-plant as indigenous in India, and the linen found in Peruvian tombs attests its having existed in that country long before it could possibly have been carried to America by Eastern intercourse. In fact, the wild American cotton-plants are specifically different from those of the Old World; but at the present day, the cotton of the West is cultivated in Asia and Africa, while that of the East has long since been introduced into the American plantations.

Cotton has been wrought into garments for the people of India for 3,000 years. Humboldt states that it formed the only clothing of the natives of Mexico, and is one of the plants they most anciently cultivated. There is evidence of the existence of the cotton-plant in America long before there was any direct communication between the civilised world and the two great portions of that continent; and we have it positively stated that the Spaniards found calico common in the dresses of the inhabitants when they conquered Mexico. It must have been known to the ancient Egyptians, and Rosellini found some of the seeds in one of the monuments of Thebes. It is conjectured that fine Indian cottons were used in ancient Rome because there was a regular commercial intercourse established, through the medium of Egypt, between Rome and India, the chief part of which was on the coast of Malabar, where weaving was practised at the remotest period of which we have any record. Fine cottons were imported into Europe in Juvenal's time, as they were ages before from India; and from China, the country of the Seres, came silk, which the Romans believed to grow on trees. Virgil, in the "Georgics," seems to allude to the cotton-plant and silk as follows:—

> "Of Æthiop's hoary trees and woolly wood,
> Let others tell; and how the Seres spin
> Their fleecy forests in a slender twine."—*Dryden's Translation.*

The Germans, who in general avoid introducing into their language words of foreign origin, call cotton *Baumwolle, i.e.* tree-wool. Cotton-wool was known in Spain in the twelfth century. It was imported by the Genoese and Venetians into England and the Netherlands in the beginning of the fourteenth century; but the use to which it was applied, except for candle-wicks, is not known. In 1430 fustians were made, perhaps invented, in Flanders. In 1534, several ships from London and Bristol traded to the Levant, and imported, among other articles, cotton-wool. It might, therefore, be expected that at this time some cotton factories would have been established in England; and this seems to be confirmed by Leland's *Itinerary*, in the reign of Henry VIII., stating that cottons were made at Bolton-le-Moors, in Lancashire, and in the neighbouring villages; also by the mention, in an Act of Parliament passed in 1552 (Edward VI.), of Manchester, Lancashire, and Cheshire cottons.

In the early stages of the trade, the raw cotton manufactured in Great Britain was chiefly the produce of the West Indies; the finer sorts came from Surinam, the Brazils, and the Isle of Bourbon. The cotton from the last-named settlement commanded the highest price in the English market up to the end of the last century, when it was superseded by the Sea Island cotton, found in Georgia, Florida, and South Carolina. The cultivation of cotton in America made very little progress at first. In 1791, sixteen years after the first sample had been sent to England, the total import of American cotton at Liverpool was sixty-four bags. Two years later an American inventor, Mr. Whitney, discovered a very simple and expeditious method of separating the wool of the cotton-plant from the seed—a process which had previously been both tedious and expensive. Yet in 1784, when an American vessel arrived at Liverpool with eight bales of cotton on board, they were seized by the Custom House officers, who had never before seen cotton from that quarter, under the impression that they had been imported from some other country. In 1785 only five bags of American cotton were imported into Liverpool, and in the following year six bags. Such were the small beginnings of that immense trade which now gives employment to millions on both sides of the Atlantic; and which, according to the Abolition party, has been the main cause of the rapid increase of the wealth and influence of the slave power in the United States.

The British colonies are capable of producing vast quantities of cotton, and in our great colony of India the plant is indigenous. It has been computed that a piece of ground of the size of Yorkshire is sufficient to produce a quantity of cotton nearly double the annual consumption of England. The supply from the British possessions is greatly increasing, especially in India, in consequence of the construction of railways and canals; whilst specimens of cotton cloth have been shown from the East and West Indies, and Australia, fully equal in quality to the best from New Orleans. A field of American cotton at the gathering season, when the globes of snowy wool are seen among the glossy dark-green leaves, is singularly beautiful; and in the hottest countries, where the yellow blossom or flower and the ripened fruit are seen at the same time, the beauty of the plantation is still more remarkable. In the early stages of the culture in India it was described as very slovenly, as the seed was sown broadcast, and the plant neglected at every stage of its growth; which, together with the carelessness of the natives in gathering the cotton, in separating it from the seeds, and in packing it, made the Indian cotton very inferior to that of the United States. Nevertheless, the perfection to which the weaving of cotton had then been brought by the natives of many parts of India, notwithstanding their rude and imperfect implements, attests at once their patience and ingenuity. A peculiar combination of heat, light, and moisture is essential to the quality of cotton, the most favourable instance of which may be assumed to be the coast of Georgia and the Carolinas. In 1852 the value of the whole crop of American cotton imported into England was £30,000,000, equal to that of the British wheat crop.

The economy of the cotton manufacture has been exemplified by modern instances, which strikingly carry conviction with them. Thus we read of the superiority obtained by the use of machinery compared with the laborious process of the Hindoo seated on the ground, with his legs in a hole, producing the most beautiful muslin; whereas the cotton can be brought 10,000 miles, cleansed, spun, woven, dried, packed, and carried back again, and then sold in the provinces where it was first grown, at a less price than that of the cloth produced by the Indian weaver. We read also of the early stages of a pound of unmanufactured cotton, which came from the East Indies to London: from London it went to Manchester, where it was manufactured into yarn; from Manchester it was sent to Paisley, where it was woven; it was then sent to Ayrshire, where it was tamboured; it came back to Paisley, where it was veined; afterwards it was sent to Dumbarton, where it was hand-sewed, and again brought to Paisley; whence it was sent to Renfrew to be bleached, and was returned to Paisley; whence it was sent to Glasgow, and was finished; and from Glasgow it was sent per coach to London. The time occupied in bringing this article to market was three years, from its being packed in India till it arrived in cloth at the merchant's warehouse in London. It must have been conveyed 5,000 miles by sea, and about 920 by land, and contributed to support not less than 150 persons, by which the value had been increased 2,000

per cent. Well, indeed, may the steam-engine have been termed "the cotton-spinner's best friend."

The first spinning-machine on record was patented in 1738, by Louis Paul, with whom John Wyatt had connected himself in partnership, though the name of Wyatt appears only as a witness. This statement is founded solely on information furnished by Wyatt's family; and the late Mr. Robert Cole, the solicitor, proved that Louis Paul was the sole inventor of a machine for spinning cotton by rollers, and that Wyatt was a workman in Paul's employ for weekly wages—as proved by patents and papers in Mr. Cole's possession, including several hundred letters, mostly relating to cotton machinery. Paul had already patented a pinking-machine, by which he made considerable profit, and a deed extant proves that he received £200 for allowing one person to use the machine. Paul's spinning-machine patent, as we have said, is dated 1738. It was then requisite for an intending patentee to make an affidavit that he was "the first and sole inventor" of the machine about to be patented, and having obtained the patent he realised considerable sums by granting licences. The deed of May, 1739, is signed by John Wyatt, as attesting witness; and in it the machine is referred to "as invented by the said Louis Paul," who covenants to fit it up. Dr. James, writing to Warren, a Birmingham bookseller, dated London, 17th of July, 1746, says, "Yesterday we called to see Mr. Paul's machine, which gave us entire satisfaction, both in regard to the carding and the spinning. You have nothing to do but to get a purchase for your grant. The sight of the thing is sufficient demonstration enough. I am certain that if Paul could begin with £10,000 he must, or at least might, get more money in twenty years than the city of London is worth." Wyatt had clearly advanced money to Paul at first, and he continued to do so, either as loans or for wages, until the total reached £200. In consequence of this debt, a mortgage deed was prepared between Paul and Wyatt, referring to 300 spindles for spinning, "according to the said invention of the said Louis Paul," which were conveyed to Wyatt, his heirs, etc., to whom Paul covenanted, within six months, to "give the same plan for working, etc., as he hath already gone by." Paul further covenanted to give to Wyatt a plan of another machine which he had invented "for the carding of wool, and other things for the use of the before-mentioned machine, or engine for spinning." Subsequently, when in the Fleet Prison for debt, Wyatt wrote to Sir Leicester Hall, "I am the person that was the principal agent in compiling the spinning engine." Paul obtained a renewal of his patent, and tried to erect one of his machines in the Foundling Hospital, whereby, as he said, "a number of mixed children, between five and fourteen years, might be enabled to earn their food and clothing." Paul's machine was ultimately abandoned, having been brought to no practical effect, although it was adduced many years afterwards as evidence against the originality of Arkwright's invention.

Tracing the means by which astonishing results have been effected, we find that in the year 1760, or soon after, James Hargreaves, an untaught weaver, living near Church, in Lancashire, began to devote his attention to the application of machinery to the preparation and spinning of raw cotton for weft. In the same year the Society of Arts offered a premium for the greatest improvement on the common spinning-wheel, and afterwards offered a premium of £100 for the construction of a machine that would spin six threads of wool, cotton, flax, or silk, at the same time. Hargreaves first invented an improved method of carding the cotton, not very different from that now in use; and in 1767 he invented the spinning-jenny, drawing several threads at once—at first containing eight spindles—made to revolve by bands from a horizontal wheel. The power of the spinning-jenny was soon increased to eighty spindles, when the saving of labour produced such alarm amongst those persons employed in the old mode of spinning, that a party of them broke into Hargreaves' house, and destroyed his machine. It was, however, again brought into use, when a second rising took place, and both carding and spinning machines were destroyed, one result of which was that the manufacture was, for a time, driven away from Lancashire to Nottingham. Hargreaves stated that he derived his idea of the jenny from seeing a hand-wheel with a single spindle overturned, when he remarked that the spindle, which was before horizontal, was then vertical; and as it continued to revolve he drew the roving of wool towards him into a thread. He then conceived that if something could be applied to hold the rovings as the finger and thumb did, and that contrivance to travel backwards on wheels, six or eight, or even twelve threads, from as many spindles, might be spun at once. This was done, and succeeded; but Hargreaves, driven by the mob, as we have described, to Nottingham, could not bear up against such ill-treatment, and there died in obscurity and distress. He had previously given the property of his machine to the Strutts, who thereon laid the foundation of their industrial success and opulence and a peerage.

The cotton yarn produced by the common spinning-wheel and spinning-jenny could not, however, produce cotton yarn sufficiently strong to be used as warp, for which purpose linen yarn was employed; and then another machine, the spinning-jenny, which took up what Hargreaves had begun, was invented by as humble an individual, Richard Arkwright, who was born at Preston in 1732, and being the youngest of a poor family of thirteen children, he received very little education. He was bred to the business of a barber, which he carried on in the town of Bolton, where remain two shops once occupied by him. He became a dealer in hair, which he collected through the country, and having dressed it, he sold it to the wig-makers. He possessed likewise a profitable secret method of dyeing hair.

Up to this time the English cotton cloths (called *calico*, from Calicut, in India, the place of their production) had only the weft of cotton, the warp or longitudinal threads being of linen, it being impossible by any means then known to spin cotton with a sufficiently hard twist to be used as a warp. The raw materials were delivered by the master to cottagers living in the villages of the district, who both carded and spun the cotton, and wove the cloth. The demand for these cottons soon became so great, that although there were 50,000 spindles constantly at work in Lancashire alone, each occupying an individual spinner, they could not supply the quantity of thread required. To remedy this state of things, several ingenious individuals had thought of spinning by machinery, instead of by the one-thread wheel. Among these was Paul, whose machines have been described. A Mr. Robert Earnshaw, of Mottram, in Cheshire, in 1753 invented a machine to spin and weave cotton at one operation, which he showed to his neighbours and then destroyed, through the generous apprehension that he might deprive the poor of bread.

Arkwright had now turned his attention to mechanics, and with one Kay, a clockmaker, who made him some wheels, they jointly devised a model of a machine for spinning cotton-threads; and next year, 1768, they erected this machine at Preston, in the parlour of the house adjoining the Free Grammar School; but dreading the hostility of the Lancashire people to their attempt to introduce spinning by machinery, they removed to Nottingham. Here wanting capital, Arkwright took his model to Messrs. Need and Strutt, stocking-weavers at Nottingham; Mr. Strutt being a man of scientific attainments, was satisfied of the nature of the proposed machine, and he and his partner joined Arkwright in 1769, and took out a patent for the machine as its inventor. It is related that when Arkwright applied to Mr. Strutt, his machine was much impeded by the fibres of the wool sticking to the roller, which defect Mr. Strutt engaged to remove on condition of participating in the profits of the result. They repaired to the mill, when Mr. Strutt, taking a lump of chalk out of his pocket, applied it to the roller, and the sticking was instantly prevented. A spinning-mill driven by horse-power was, at the same time, erected and filled with frames. In 1771 Arkwright and his partners established another mill at Cromford, in Derbyshire, the machinery to which was set in motion by a water-wheel; and in 1775 he took out a second patent, with additions to his former one. This was a combination of the carding and spinning machinery with two pairs of rollers, the one revolving faster than the other, which forms the peculiarity of the machine.

The most important of Arkwright's contrivances was his drawing out the cotton to a harder twisted thread, so as to be used for warp as well as weft. This was managed by a principle altogether novel. The cotton was first drawn from off the skewers by one pair of rollers made to move at a comparatively slow rate, and which formed it into threads of a first or coarser quality; but at a little distance behind the first was placed a

second pair of rollers—revolving three, four, or five times as fast—which took it up when it had passed through the others, the effect of which was to reduce the thread to a degree of fineness so many times greater than that which it originally had. The first pair of rollers might be regarded as the feeders of the second, which could receive no more than the others sent to them, and that again could be no more than these others themselves took up from the skewers. As the second pair of rollers, therefore, revolved, we will say five times for every revolution of the first pair—or, which is the same thing, required for their consumption in a given time five times the length of thread that the first did—they could obviously obtain so much length by drawing out the common portion of cotton into thread of five times the original fineness. Nothing could be more beautiful or more effective than this contrivance, which, with an additional provision for giving the proper twist to the thread, constitutes the *water-frame*, or *throstle*, so called from its being originally moved by water-power. Such, in principle, were the two great inventions that effected an entire change in the manufacture of cotton, wool, and flax.

The idea of spinning by rollers Arkwright accidentally derived from seeing a red-hot bar elongated by being made to pass between two rollers; and though there is no mechanical analogy between that operation and the process of spinning, it is not difficult to imagine that by reflecting upon it, and placing the subject in different points of view, Arkwright might be led to this invention, which he specially claimed as his own. Of other machines which he included in his patents, he was rather the improver than the inventor; and the original spinning-machine for coarse thread, the spinning-jenny, Arkwright admitted to have been first conceived by Hargreaves. Previous to this time no establishment of a similar nature had existed, none at least to which the same system of management was applicable, and it strongly marks the judgment and mental powers of Arkwright, that although the details of manufacturing or commercial business were altogether new to him, he at once introduced a system into his works which has since been universally adopted by others, and which, in all its main features, has remained unaltered to the present time. In the year 1775 he completed a series of machinery so various and complicated, yet so admirably combined and well adapted to produce the intended effect in its most perfect form, as to excite the astonishment and admiration of every one capable of appreciating the ingenuity displayed and the difficulties overcome. At the expiration of the partnership of Strutt and Arkwright they separated. Arkwright went on by himself at Cromford, and the Strutts for themselves at Belper. A fierce spirit of detraction strangely represented that Arkwright stole the invention of another; but Mr. William Strutt, who was a competent judge on such subjects, attested that Arkwright was a skilled mechanic, and quite equal to such an invention. He did not, however, enjoy the rights of his ingenuity without opposition alike from the manufacturers, and the spinners, and the weavers. His factories were attacked, his patents were invaded, and the merit of his being an original inventor denied. Circumstantial accounts of this system of injustice are to be found in the histories of the cotton manufacture, but cannot be quoted in this sketch. The "Encyclopædia Britannica" has this conclusion: "We have access to know that some of Mr. Arkwright's most intimate friends never had the slightest doubt as to the originality of his inventions, and some could speak from their own personal knowledge, and their testimony was uniform and consistent," and such became the opinion of the principal manufacturers of Manchester. "If," says the "Penny Cyclopædia," "the evidence be fully weighed upon which it has been attempted to convict Arkwright of the serious charge of pirating other men's ideas, we think it will rest upon very slight grounds, while the proofs which he exhibited of possessing talents of the very highest order in the management of the vast concerns in which he was afterwards engaged, are unquestionable." It was not, however, until after the lapse of five years from their erection, that from the works at Cromford any profit was realised; but from that time wealth flowed in abundantly. The establishments were greatly extended, and new ones were formed, and success continued to flow, notwithstanding Arkwright's patent had been cancelled by law. Meanwhile, he had almost built the town of Cromford, and lived in patriarchal prosperity amidst the scenes of industry where he raised up his own fortune. He served as High Sheriff of Derbyshire in 1786, and received knighthood from King George III. But his health failed, and he died in 1792, in the sixtieth year of his age, leaving a fortune little short of half a million, besides having presented each of his ten children with £20,000. No man ever better deserved this good fortune, or had a stronger claim on the respect and gratitude of prosperity. His inventions opened a new and boundless field of employment, and while they have conferred infinitely more benefit on his native country than she could have derived from the absolute dominions of Mexico and Peru, they have been *universally* productive of wealth and enjoyment.

The power which gave motion to the rollers and spindles of Arkwright and his fellow-inventors was supplied at first by falls of water, when manufacturers of necessity planted their establishments in districts where water-power was readily obtained, however inconvenient these situations might be in other respects. Watt's improvements in the steam-engine, however, supplied them with what they wanted, at a higher price certainly, but at any place and at any time they chose. As soon as steam-engines were used to drive the machinery, factories might be set up in towns, made independent of drought or flood, and wrought by a motive power whose energies could be adapted with the utmost nicety to the work required. Steam-engines were accordingly employed in turning the rollers and other machines used in spinning the cotton, as early as 1785, and the inventions of Watt and Arkwright, when thus combined, gave an impulse to the manufacture, which neither of them by itself could have produced. To show the advantages that have resulted from this combination of intellect, industry, and capital, it may be said that the quantity of cotton introduced into this country was under 5,000,000 pounds when the inventions of Arkwright were projected; in 1868 it was 11,857,893 cwt.

CIVIL ENGINEERING.—VI.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

CANALS (*continued*).

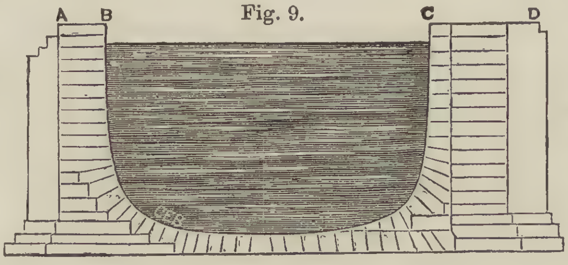
The loss of water in a canal is variable, and at some periods excessive. We have already pointed out the necessity of providing for this loss by effecting a communication between the summit level of the canal and some invariable source of supply. This point is of paramount importance, and demands a still closer notice. Supposing the supply to be drawn from a river, it is usual to construct a weir across it, and after damming up the stream, to admit a portion into the canal. Thus whilst the level of that portion of the river above the weir will vary very slightly under the influence of drought or rainfall, the amount admitted into the canal will be proportionally constant. Under all circumstances of supply, however, it is imperative to provide a carefully constructed outlet for any excess of water arising from floods; the position of this outlet will, of course, be in the same section of the canal with the supply. The *character* of the water admitted to the canal is a matter of importance. If derived from a turbid source it should, if practicable, be passed through filtering beds, or reservoirs, in which any suspended matter may be allowed to settle. This plan will permit of a much longer period elapsing before the water need be drawn off the canal for cleansing the channel, for under all circumstances an accumulation or deposit of mud in the bed will arise, and unless a system of *sluicing*—a plan adopted to a great extent in Italy—be employed, the water must be occasionally drawn off; and as from necessity all navigation has to be stopped during this period, every means should be adopted to obtain *pure* water to supply the loss.

The course of the canal, which we have stated must be guided by commercial as well as engineering considerations, needs a few words of consideration. It is not always possible, owing to the nature of the ground, to lead the main channel of a canal through a town. If such is the case, an offshoot or branch leading to some convenient locality in the town, and terminating with a wharf, must be constructed.

A certain proportion must be allowed to exist between the *size of the locks* and the *interval between* them. The reason for this is that a lock full of water drawn off from any interval above it for the purposes of navigation shall not lower the water in that interval excessively, that is, so that a loaded

barge could not float. As a matter of course, the dimensions of the channel of a canal are in terms of the barges which navigate it. Thus if we suppose the maximum draught of any boat $= D$, its extreme breadth $= B$, and its extreme length, including the rudder, $= L$, it is usual to allow the depth of water (D') to be $D + 1{\cdot}5$ feet, in which D usually equals 5 feet; the width at the surface is usually $3(B + 3D') = 40$ feet; and the width of the bottom $3B = 25$ feet. The width of the channel becomes greatly narrowed as it approaches the lock, where the width is the least. A lock need never exceed the breadth of a barge by more than 1 foot or $B + 1$ foot. Again, the length of the lock should not exceed $L + 1$ foot, and the depth $D + 1\frac{1}{2}$ feet. An ordinary canal lock is 75 feet long, 8 feet broad, and 5 feet in depth over the mitre-sill. Now the *least* length allowable between locks should be such that 12 inches of depth over and above what a loaded barge will draw shall, when the barge is enclosed in the lock and the water drawn off, never lower the water in the interval above more than 6 inches. Hence when the chambers of the lock are large and the canal narrow, a greater distance must be arranged between the locks.

Fig. 9.



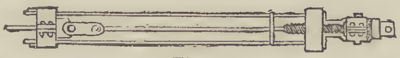


Fig. 12.

Fig. 11

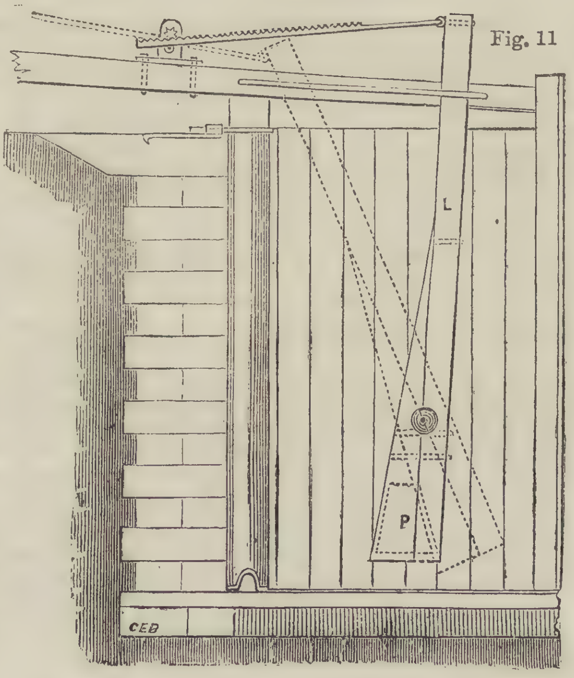
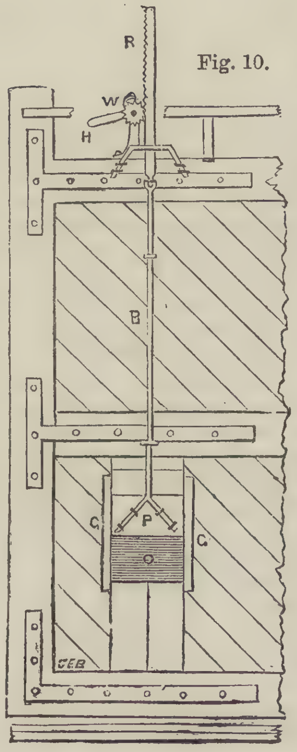


Fig. 10.



The Saone and the Loire are united by the canal of Briare, navigable to ships of small burden; hence the respective dimensions are larger than those given above. The locks are 110 feet long and 17 feet wide, giving a superficial area of 1,870 feet. If the fall be 6 feet 4 inches, 11,843 cubic feet will be drawn from the upper section; if 8 feet 6 inches, 15,859 cubic feet; if 10 feet 6 inches, 19,635 cubic feet. The canal being 48 feet wide at 3 feet below the ordinary level of the water, the length of the interval to the next lock should be 446 feet, so that the fall of 6 feet 4 inches in the lock should not lower the water in the interval more than 6 inches. It must, however, be 607 feet when the locks are 8 feet 6 inches of fall, and 755 feet when the fall is 10 feet 6 inches.

The importance of attending to these points will be seen from supposing a case where the reverse has occurred from necessity or oversight. If two locks, having a fall of 8 feet 6 inches, were only separated by 160 feet, the water drawn from the interval for the purpose of mounting the boat would lower it nearly 26 inches, and there would not remain sufficient to keep it afloat; consequently it would be necessary to draw a lockfull from the upper interval, and then a second to cause it to rise, whilst only one would be required if the locks were at a sufficient distance. In many instances canals have been cut to connect two tidal rivers. There is in such a case no difficulty in obtaining the water for the navigation, as the whole channel may be re-filled at every tide up to the level of that tide. In this case, however, the entire channel must have a much larger capacity, as compared with that of the locks, than is required in other cases, because, as the supply is only obtainable at stated intervals, sufficient must be admitted at these periods to compensate for the whole loss arising from the navigation during the interval. Hence the canal becomes its own reservoir.

The form of the chambers of locks should be a parallelogram; it is the most convenient, and expends the least quantity of water. In the canal of Languedoc the form is oval, but the greater loss of water expended more than counterbalances the advantage of greater strength obtained by the curved wall. The walls of a lock should not be perpendicular outside. The pressure of water being proportionate to the height of the column, the walls must have the greatest width at their base, and narrow gradually towards their summit. Inside, the wall may be perpendicular, except at the bottom, where they may have the same curve as the sides of the boats. The walls should not be less than 4 feet 3 inches thick at the level of the water, and should have throughout them a lining of bricks set in cement to prevent filtration of the water. The openings of the lock are gradually widened, after leaving the mitre-sills, by what are termed *shoulders of defence* facing the higher level, and *discharging walls* facing the lower level. The continuations of these are termed *wing walls* and *return walls.* The whole of these are built of one continuous piece of masonry upon each side of the lock respectively, and have for their object the prevention of the water passing round and behind the chamber-walls, and the resistance necessary to withstand the thrust of the gates when under the influence of the water-pressure. In Fig. 9 we give an elevation of the usual form of a lock-chamber contiguous to the gate. The finished masonry extends from A to D, from which points the shoulders spring, diverging right and left. The position of the anchors which support the collars or hanging-pieces of the gates, as shown at Fig. 7 (Vol. I., page 386), is allowed for during the building of the side walls by the

insertion of solid blocks of stone. The platform of the lock is a point requiring great care in construction. It has to receive the shock of the water when admitted by the opening of the sluice, and is very difficult to keep in repair. It is usually formed of timber laid upon a foundation of piles, with a layer of masonry beneath it. The ends may with advantage be worked into the masonry of the side walls. Where it is possible to obtain them, large flagstones are preferable for the surface of the platform.

The timbers forming the gates of locks will vary in size according to the dimensions of the opening, and their respective depths below the water-level, the lower rails having to support a greater pressure than those above. The weight of water supported by each horizontal rail will be found by multiplying their length, the interval from one to the other (usually 38 inches from centre to centre), the height of the water above the centre of the rail, and the product by 62 lb. (the weight of a cubic foot of water), the last product of these measures giving the number of pounds which the rails ought to support throughout their whole length. For small gates the timbers or rails may be from 4 to 5 inches square, and for larger, from 7 to 8 inches; the latter being sufficient for a fall of 10 ft. 6 in., with a width of 17 feet between the hanging posts, six rails being put in the height. Whilst on the one hand it is desirable to have an excess of strength above the calculated requirement, it is on the other hand undesirable to make this excess excessive, as so much more weight is injurious to the supporting collar and the masonry to which it is attached. The diagonal direction of the braces may be dispensed with by the substitution of a bar of iron placed diagonally from the supporting collar to the lower end of the shutting-post. The escape of water through the gates must in every way be guarded against. It is very difficult, indeed almost impossible, to prevent its escape through the joint of the shutting-posts, because of the difficulty of making them touch throughout their own length. To obviate this they should be cut in a circular form, one concave and one convex; the curvature should be with a radius of about 12 feet. The rails are mortised into the uprights, and are further strengthened by strong angle irons and T-pieces.

The sluice is ordinarily an opening, O (Fig. 10), left in the framing of the gate, and closed by a paddle, P, working vertically in guides G, G, and raised or lowered by an iron bar, B, terminating at the top in a rack, R, actuated by a pinion, W, and handle, H.

In Fig. 11 is shown another kind of sluice, in which the paddle, P, moves laterally, being fixed to the short end of a lever, L, heavily weighted at the lower or paddle end. The movement is given by a rack and pinion working nearly horizontally. The idea of this arrangement is that when no water is pressing against the paddle, the weight at the bottom draws it over the aperture, and when drawn back by the toothed gear it will remain back until the water-pressure ceases through a level having been obtained. In some cases screws are employed to raise the paddles (Fig. 12). This plan is adopted at Dunkirk. There are, as we have intimated in a former chapter, other modes of raising or lowering the barges from one level to another besides locks. The "lift" is a plan adopted upon the *Grand Western Canal*, and has certain advantages over the lock. These lifts are 46 feet high, and consist of two chambers, having a piece of masonry between them. Each chamber contains a timber cradle, in which the boat is placed which requires to be raised or lowered. When on a level with the canal the cradle allows the boat to swim into it by raising a water-tight gate at the end. The two cradles, when full of water, or when containing a boat, balance each other, being suspended by strong chains, which pass over iron wheels placed above the level. An additional 2 inches of water in the cradle not containing a barge is sufficient to raise the barge in the other. The barges using these lifts weigh 8 tons, and occupy 3 minutes in passing up or down the 46 feet, and only 2 tons of water are consumed in the operation, whereas 3 tons would be expended for boats of this tonnage in the ordinary way. If an inclined plane is employed to raise or lower the boats, they are floated upon a sledge, which is drawn up by a steam-engine.

Notwithstanding the obvious advantages of conveying heavy merchandise by water, it is remarkable that scarcely any attention was paid to the subject in this country until about the middle of the sixteenth century, when it was proposed to render the Isis and the Avon navigable, and then to unite the two streams by a canal 3 miles long. The first canal of importance was the Duke of Bridgewater's, between Worsley and Manchester, executed by Brindley. Several remarkable instances of bold and successful engineering occur upon this canal, especially the aqueduct over the Irwell at Barton, consisting of three semi-circular arches, the centre arch being 63 feet span and 39 feet over the river. Since the year 1776 no less than 2,400 miles of canal have been made in Great Britain. One of the most celebrated is the *Caledonian Canal*, uniting Fort William with Inverness. The entire distance between these points is upwards of 100 miles, but in consequence of the natural position of the chain of Lochs Ness, Oich, Lochy, Eil, and Linnhe running in an almost right line in a direction from north-east to south-west, only 21 miles of canal were requisite to render the entire line navigable for vessels drawing 15 feet. The breadth of the canal and enlargements of the locks is 122 feet at top, and 50 feet at bottom, and the depth 20 feet. The slope of the sides is as 2 of height to 3 of breadth, and is continued to within 2 feet of the water-level, the bank being 6 feet wide. Throughout the entire canal there are 23 locks, each being 40 feet wide and 172 feet long. Somewhat to the south of the northern entrance an enlargement of the canal to 162 yards of breadth for 967 yards of length constitutes a floating dock for repairs and other purposes of 32 acres. Loch Ness, the most northernly of the chain, has a level 32 feet above the canal, to which vessels are raised by the four Muirtown locks, each 180 feet long, and 40 feet broad. The addition of Loch Ness gives at once a natural addition of 22 miles to the navigation. At its south-west extremity five more locks raise the navigation 40 feet higher to Loch Oich. The waters of Loch Lochy are 10 feet higher than those of Loch Oich, and are reached by the intervention of a single lock. This loch forms the summit of the canal, which then descends 64 feet to Loch Eil by eight locks. The whole of these eight connected locks are formed of solid masonry 1,500 feet long. The foundations of the embankment at Clachnacharry are in mud, which is so soft that an iron rod could be thrust down 55 feet with ease. The mode in which the lock at this point was constructed is so instructive that we give it. The immense depth of mud precluded the use of a coffer-dam; an iron railway was accordingly laid down, on which the heavy clay found close by was carted, and the two banks of the canal were formed by "tipping" as far as where the depth of water at an ordinary neap tide was 20 feet, and when the site of the intended lock was approached, the banks were united into one mass. The weight of the clay compressed the soft mud, and squeezed out the water. Upon this mound of clay a quantity of stone was laid, and allowed to remain for six months, by which time the mound had sunk 11 feet, and become consolidated. The pit for the lock was then excavated out of the consolidated clay, and the water kept down by a steam-engine of nine-horse power. At the bottom of the excavation rubble stone masonry was laid with hydraulic mortar to the thickness of 2 feet in the middle of the chamber, increasing to 5 feet on each side, and upon this an inverted arch of masonry was struck, and the side walls built. The entire cost of the canal was £982,359, and the quantity of Baltic timber expended upon the works was so great that the price rose from 2s. 6d. to 7s. per cubic foot during the time occupied in its construction.

THE ELECTRIC TELEGRAPH.—VIII.

THE MORSE PRINTING TELEGRAPH—RINGING-KEY—CODE—THE RECEIVING INSTRUMENT—ARRANGEMENT OF INSTRUMENT-ROOM.

The telegraph instruments we have already described are those that transmit their signals by the property which the electric current possesses of reversing the poles of a magnetised needle. We must now consider the next class of instruments—namely, those in which the power of the current to convert a bar of soft iron into a temporary magnet is turned to account. As we saw in our lessons in "Electricity" in THE POPULAR EDUCATOR, we have only to take a rod of iron, and wind some insulated wire many times round it, and then, by sending a current along the wire, we at once convert the rod into a powerful magnet. This magnetic power continues as long as the current passes, but

ceases as soon as it is in any way interrupted. Now it is pretty clear that we may in several ways avail ourselves of this power in the transmission of messages, since it is perfectly immaterial at what part of the circuit the current is interrupted.

The telegraph instrument which, next to the needle instrument, has come into most general use, is one of this class, and is known as the "Morse Instrument," after Professor Morse, by whom it was invented. This instrument is found in practice to answer extremely well; it may, in fact, be in most respects regarded as the best instrument known for general use, being simple in its construction and action, and not liable easily to get out of order. One great advantage that it possesses over the needle instrument is that it prints or embosses its own message on a strip of paper, and thus leaves a permanent record; whereas, in those already described, the operator must observe the very transient signals, and at once write them down or dictate them to another clerk. If a word or letter be dropped, the sender must be interrupted and made to repeat; while in the Morse the whole message is printed, and the receiving clerk can then carefully read and transcribe it at leisure. The original strip may also be preserved for reference if necessary; and, in addition to this, the fact that the transmitting clerk knows that he is actually printing his message, and that thus any mistake will at once be brought home to him, tends to render him much more careful.

The peculiar click of this instrument will be familiar to many travellers, as it may very frequently be heard at work in the booking offices of railway stations.

The "transmitter," or, as it is usually called, the "ringing-key," of this instrument is much simpler in its construction than that required for a needle instrument, since the current has only to be sent in one direction. All that is required is an arrange-

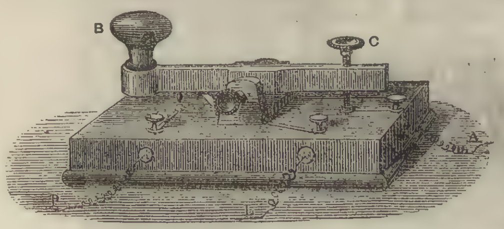


Fig. 34.

ment by which the circuit can be interrupted, and a battery current made to pass along it at pleasure.

All this is easily effected by the instrument shown in Fig. 34. The base is made of some hard, dry wood, usually mahogany, and a stout brass rod is mounted on an axle fixed to this; a handle, B, being affixed to one end of it, and an adjusting screw, C, to the other. One battery wire, P, is connected to a binding-screw, which communicates with a small anvil placed under B, and is usually tipped with platinum; the other battery wire is joined to the earth-plate. L is the line-wire, which it will be observed communicates through a binding-screw with the rod B C.

Above the small anvil is a short piece of wire which comes into contact with it when B is pressed down, and thus causes the current to pass from P to L, and on to the distant station. A spring, however, keeps this point away from the anvil when the instrument is at rest.

The screw C presses on another plate or anvil at the other end, from which a wire, A, leads to the receiving apparatus and on to earth. The reason of this is that the wire L is used for the transmission of messages in either direction. When, therefore, the key is at rest, as shown, any current arriving by L passes through C and A to the receiving portion of the apparatus, and there makes the required signals. When, however, we want to send a message, and press down the key for that purpose, our own receiver is cut out of circuit, and the current only goes through the distant instrument.

One inconvenience sometimes arises from this arrangement. If the line-wire were in any place broken or injured, no current would pass, and the operator might continue to send the message, supposing all was right, for as the current does not pass through his own instrument, he would not know that the circuit was broken. The receiver, too, might want to interrupt him, but with this arrangement would be unable to do so. A small galvanometer is therefore always placed in the course of the line-wire, and the constant currents sent cause the needle of this to keep continually oscillating. If now the distant operator wishes to interrupt, he merely presses down his key, so as to

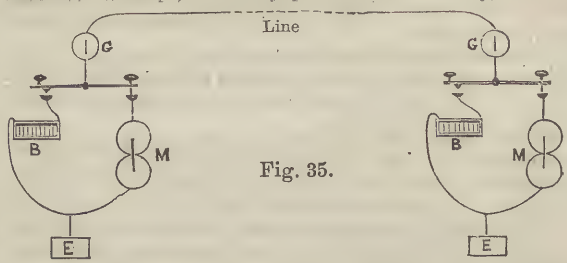


Fig. 35.

remove the screw C from its anvil, and thus break the circuit. No current will now pass, and the sender, perceiving that his galvanometer has ceased to vibrate, will at once wait and hear what the distant station has to say. It will thus be seen that this small galvanometer is a very important part of the apparatus.

The sketch in Fig. 35 will render clear the manner in which the different pieces of apparatus are joined in circuit in the way we have been explaining. For the sake of simplicity, we have here represented the key as consisting of a bar of metal, the centre of which is in connection with the line-wire, while the ends may communicate with the battery, B, or the instrument. M; and by referring to the illustration of key already given, it will be seen that this is essentially the case. G, G represent the galvanometers placed in the circuit of the line-wire, and E, E the earth-plates.

The receiving part of the instrument is much more complicated in its construction. The message is printed on a strip of paper about half an inch wide, a long roll of which is placed on a drum supported above the body of the instrument. The end of this riband passes between two rollers, which are set in motion by means of clockwork, the driving power being in some cases derived from a spring contained within a barrel, and in other cases from a weight. A fan is attached to some portion of the clockwork, so as to render the motion of the paper uniform. This part of the apparatus does not require further description here, and almost every maker adopts some special form of construction peculiar to himself.

The electrical portion of the instrument is that which more especially concerns us, and this is remarkably simple in its make and action. The line-wire is connected to a binding-screw attached to the base of the instrument, and from this the current passes round the coils which surround two iron rods placed side by side. In Fig. 36 we have a view of the essential parts of the apparatus. A is one pole of the electro-magnet, and B its keeper, which is fastened to the lever B D. This oscillates with very little friction on pivots at C, and its play is limited by the arm, I, attached to it, and the set-screws, G G. The end of A is usually covered with a piece of thin paper or a layer of varnish, as otherwise a little magnetism often remains in it, causing the keeper B to remain in contact after the current has ceased. A spiral spring, capable of adjustment by the milled head H, is fastened to the end of the lever remote from the magnet, and when

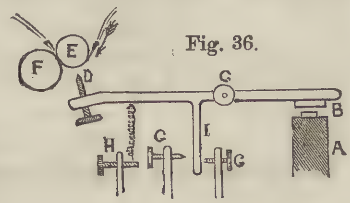


Fig. 36.

the current is not passing holds the keeper as far away from the magnet as the set-screws, G G, will allow. D is the style, or pen, and is so placed that it is opposite a groove in the roller E. The paper riband is drawn between E and F

As soon now as a current is transmitted along the line-wire, and passes round A, it converts it into a magnet, and overcoming the spring at H, presses the style D against the roller, and thus embosses or indents the paper strip.

If this strip be in motion we shall evidently have a continuous line traced along it so long as the current passes, and when we

interrupt the current there will be a corresponding blank. We might in this way send strokes of various lengths, but this would be found inconvenient, since the paper does not always travel at exactly the same rate. Only two signs, therefore, are employed—a dot, which is produced by sending a very brief current, and a dash, which is made by keeping the key pressed down for an instant.

Sometimes, instead of a blunt point at D, we have a wheel with a narrow edge, which is in contact at one side with an ink roller. In this way the marks are inked on the paper strip, instead of being embossed.

We have, then, here, as in the case of the needle instrument, two distinct signs—the dot and the dash—and by a judicious combination of these we can send any letter in the alphabet we choose. The very same code is employed as that used with the single-needle instrument; in fact, the code used for that is merely the Morse code translated, an inclination of the needle to the left being considered the equivalent of a dot, and one to the right representing the dash. We append, however, the full code of the Morse, which is now adopted in nearly all countries.

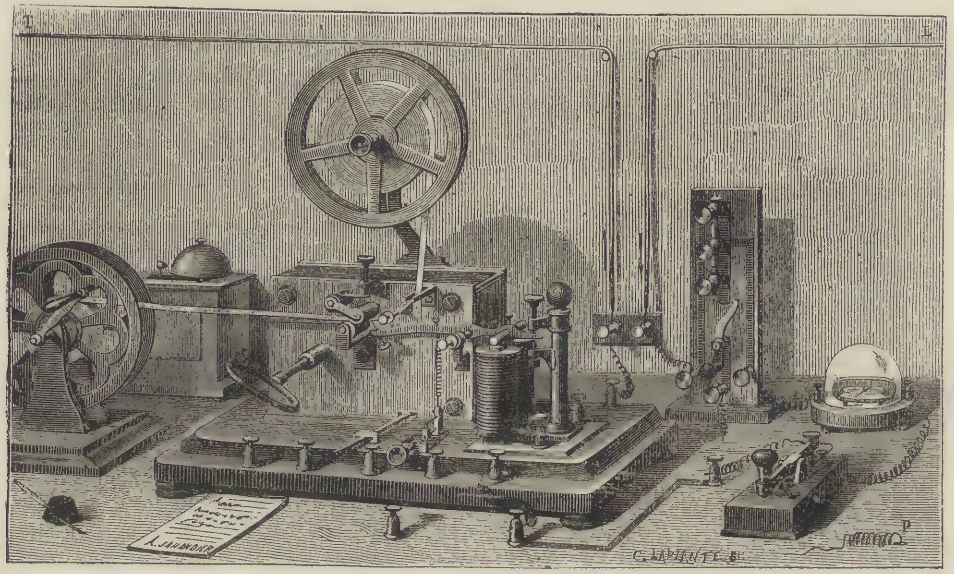


Fig. 37.—INTERIOR OF AN INSTRUMENT-ROOM.

The letters of the alphabet are thus represented :—

A .—	J .———	S ...
Ä (æ) .—.—	K —.—	T —
B —...	L .—..	U ..—
C —.—.	M ——	Ü (ue) ..——
D —..	N —.	V ...—
E .	O ———	W .——
F ..—.	Ö (œ) ———.	X —..—
G ——.	P .——.	Y —.——
H	Q ——.—	Z ——..
I ..	R .—.	Ch ————

The following code is adopted to represent figures :—

1 .————	6 —....
2 ..———	7 ——...
3 ...——	8 ———..
4 ....—	9 ————.
5	0 —————

In this code, as will be seen, no letter requires more than four signs, while figures are all represented by five. The stops can easily be learnt from the needle-code in Lesson V. Spaces about equivalent in length to the dash are left between each letter, those separating the words are about three times as great. We give as an example a specimen of a strip as received, the equivalent letters being placed under each sign.

—.—.	.—	...	...	.	.—..	.—..	.—.—.—	...
C	A	S	S	E	L	L	,	S

—	.	—.—.	....	—.	..	—.—.	.—	—..
T	E	C	H	N	I	C	A	L

.	—..	..—	—.—.	.—	—	———	.—.	......
E	D	U	C	A	T	O	R	.

The main difficulty in transmitting messages with this instrument is found in arranging the spaces properly; and to meet this Professor Morse introduced a transmitting plate, in which each letter was represented by strips of ivory and brass inlaid in a board. Any letter could then be sent by merely drawing a metal style connected with the line-wire over the sign on the plate, but this never came into general use. The full construction of the receiving apparatus, and the general arrangement of the instruments in the office, will easily be understood by reference to Fig. 37, which shows the interior of an instrument-room completely fitted.

In the instrument here shown, the set-screws which govern the play of the lever are placed at the end of the lever instead of on an arm attached to it, as seen in Fig. 36, but they act in the same way. The course of the paper strip can now be traced as it leaves the upper drum, passes between the rollers, and, after being embossed, is wound on to the second drum to the left. Both these are so made that one side will take off, and allow the disc of riband to be removed or replaced. The clockwork is contained within the brass case of the instrument, the key by which it is wound up being seen.

P is the battery-wire just disconnected from the ringing-key, behind which is the galvanometer. To the left of this is a switch, by which the current as it enters may be directed at pleasure to the alarum or the instrument, or, in the case of an intermediate station, be made to pass straight on. The wire L is that which communicates with the line, while T is connected to the earth-plate. The alarum is seen behind the drum on which the riband is coiled.

The only other point to which we need refer is the small lever seen at the base of the receiving instrument: by means of this the clockwork can be started or stopped at pleasure. It would not do for the paper to be continually unwinding; the clockwork is therefore stopped by means of this lever. As soon as the alarum rings to indicate that a message is coming, the clerk alters the switch, so as to direct the current to the instrument. He then gives a signal to show he is attending, and starts the clockwork. The riband then commences to unwind, and is embossed with the message which he can afterwards transcribe.

THE STEAM-ENGINE.—VIII.

By J. M. Wigner, B.A.

CONDENSER—AIR-PUMP—FORCE-PUMP—GOVERNOR BALLS—THROTTLE-VALVE—HORSE-POWER—WATT'S INDICATOR.

In non-condensing engines the steam, after having done duty in raising or depressing the piston, is allowed to escape by the exhaust direct into the air. The consequence of this is that the full pressure of the air is exerted against the opposite side of the piston to that on which the steam is acting, and all this pressure has to be overcome before the piston can be moved. In the condensing engine which we are now describing this source of waste is almost obviated. The cylinder here is nearly void of air, so that if we can in any way condense the steam that fills the cylinder after it has accomplished its work in driving the piston to the end, we shall have a vacuum into which the piston may return, and shall thus avoid all loss of power from this cause. This object is accomplished by means of the condenser, which is another of the many great improvements in the engine that are due to the genius of James Watt.

In the earliest engines the plan adopted was to cool the cylinder by the application of cold water to its exterior surface. This plan was very slow, and caused a great loss of heat, as the cylinder became so cold that a portion of the fresh steam as it entered was expended in raising its temperature again, and in so doing became condensed on its inner surface.

The next improvement consisted in injecting a jet of water into the cylinder, and in this way the condensation was effected much more rapidly, but still there was much waste of heat.

At last Watt introduced the separate condenser, which has been found to answer remarkably well, and to effect a very great saving. The condenser is represented at O (see Fig. 32, page 17), and consists of a large air-tight vessel communicating with the exhaust by means of the pipe seen under the valve facing.

A small force-pump, R, worked by a rod, H, jointed to the working beam, raises cold water from a cistern or well, and forces it along the pipe, T, into the condenser. The inner end of this pipe is fitted with a rose, so that the water is scattered in a fine shower, and thus condenses the steam very rapidly, so that a considerable degree of exhaustion is maintained. A pressure gauge is usually affixed to the condenser, so as to indicate readily the exact degree of condensation produced.

By the use of this arrangement the condensation is practically instantaneous, and there is no delay in commencing the alternate stroke. The injected water added to that produced by the condensation of the steam accumulates in the condenser, and would soon impede its action were no means provided for removing it, and any air which may find its way in with it. An air-pump, M, is therefore placed by its side, and motion is imparted to it by means of the pump-rod, F, which is affixed to one rod of the parallel motion.

A pipe, closed by a valve opening outwards, leads from the lower end of the condenser to this pump, and along this the condensed water and the air pass, and are delivered into the hot cistern, N. The air, of course, bubbles up through the water and escapes.

The steam when it leaves the cylinder has still a large amount of heat stored up in it, and this raises the temperature of the injected water, so that the water in N is quite hot. It is used, therefore, to feed the boiler, into which it is injected by the pump, Q, along the feed-pipe, S. As much of the heat in the steam is latent, a large amount of water is required to condense it. If the condensing water has a temperature of about 60° while the temperature when condensed is 100° or 120°, nearly twenty pounds of water will be required to one pound of steam. This is, of course, very much more than is required for feeding the boiler; and hence, in many engines, arrangements are made by which a portion of the condensed water leaves the condenser at a temperature very little below the boiling-point, and with this the boiler is fed. The more usual plan, however, is for the feed-water to have a temperature of about 120°.

Various other kinds of condensers are often employed in place of that already described. In steam vessels "surface condensers" are commonly adopted. In these the steam is made to pass through a series of brass or copper tubes, on the exterior of which the cold water plays, and thus condenses the steam. In other cases the positions are reversed, the water being made to pass through the tubes while the steam is condensed upon their external surfaces, and this plan appears to meet with more general approval. In this kind of condenser it is well to let the circulation be as rapid as possible, and the more rapid it is the less the area of condensing surface that will be necessary to ensure efficiency. The usual proportion allowed is from twelve to eighteen square feet for each nominal horse-power of the engine, but with a rapid circulation less than this will suffice. There must, however, be no delay in the condensation, or else a resistance will be offered to the movement of the piston.

The supply of the water and steam should be so arranged that the steam as it enters the condenser is first exposed to the action of the heated water just leaving it. In this way the cold water entering meets the steam when its condensation is nearly completed. Condensers of this kind answer very well, but it is not often found necessary to employ them except in the case of marine engines.

We have now referred to the various parts of the engine that are shown in Fig. 32: there is, however, one important part omitted there. In most cases it is an important thing to maintain a nearly uniform rate of motion. Without some regulator, however, this cannot be attained; the pressure of steam in the boilers often varies considerably from time to time; the load of the engine is also subject to constant fluctuations; and in a large factory some of the machines are frequently stopped for a time, and others again are set to work. The tendency of all these alterations is to produce great variations and irregularities in the speed of the engine, and cause thereby much inconvenience.

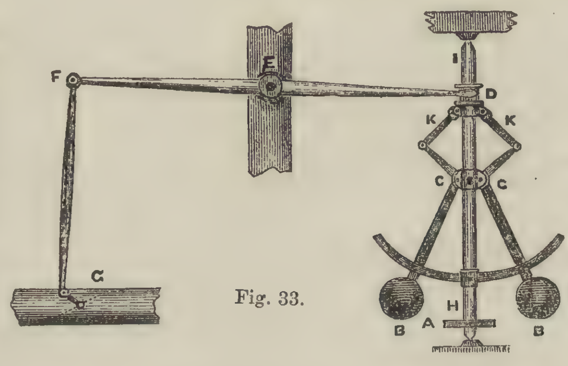


Fig. 33.

The manner in which the speed is usually regulated is by means of a throttle-valve, acted upon by governor balls, as seen in Fig. 33. This valve consists of a metal disc, G, placed in the steam-pipe; it is mounted on an axis passing through it edgeways, so that when it is horizontal the passage of the steam is not materially affected, but as it is inclined the passage becomes more and more closed. In some convenient part of the engine is placed a vertical axis, H I, mounted on pivots at each end, and driven by an endless band passing round the driving pulley A, and also round the axis of the fly-wheel or some similar part. On this axis are jointed two bent levers, C B, C B, each of which carries at its lower end a heavy metal ball, B.

Above C C is a loose collar, D, supported by two rods, K K, hinged to the other ends of the levers, and moved by them. A groove in this collar holds two pins in the crutch of the lever, D E F, and thus moves the throttle-valve, G. If now the load of the engine be diminished, or from any other cause the speed increase, the balls at once, by centrifugal force, fly further apart. In so doing they raise the upper ends of the bent levers, and with them the collar D. The result of this is that the end, F, of the lever is depressed and the valve partially closed, and the supply of steam being in this way diminished, the speed of the engine is at once reduced. If on the other hand the engine moves more slowly, the governor balls fall, and thus open the throttle-valve to a greater extent. In this way the speed is maintained very nearly at a uniform rate. In some engines now made, the governor balls, instead of working a throttle-valve, are connected with a second slide-valve, and thus alter the period of the stroke at which the steam is cut off, and in this way regulate the speed.

A regulator of the kind already described is that most gene-

rally used. Its action is, however, far from perfect, as it takes some little time for the engine to recover its rate of speed after a sudden variation in the load. Many alterations have been suggested: in some of these the governor balls are retained, but the construction of the valve is very materially modified, so as to render it much more sensitive. In one form, which has been found to answer well, a double spindle valve is used in place of the disc, two valves being mounted on the same spindle, so that a trifling movement of this materially alters the rate at which the steam is allowed to pass.

Before passing on to notice the construction of other kinds of engines, it will be well to explain the manner in which the power of an engine is described. In reading any books or papers relative to engines we constantly find the term "horse-power," the engine being said to have so many horse-power.

Now it is important for us clearly to understand what is meant by this expression, especially as it is often somewhat vaguely employed, being in some cases used to denote "nominal" power, and in others "actual" power. The latter, of course, varies with the pressure of the steam employed, but the former is an arbitrary term expressive of the size of the engine, and may generally be taken as expressing the actual power when the steam has a working pressure of 7 pounds to the inch in the case of a low-pressure engine, and 21 pounds in the case of a high-pressure engine. The actual steam pressure usually exceeds this, and as a result the actual power of any engine is usually much in excess of the nominal.

The term "horse-power" was originally an arbitrary standard taken to express the work capable of being, under ordinary circumstances, performed by a horse, and is now used as expressive of a force capable of raising 33,000 pounds to the height of one foot in the space of a minute. The actual horse-power of any engine may therefore be easily calculated.

By means of an "indicator" or gauge the actual pressure in the cylinder is ascertained, and from this a deduction of $1\frac{1}{2}$ pounds is made to allow for loss by friction, imperfect vacuum in the condenser, and similar causes. We then ascertain the area of the piston in square inches, and multiplying this by the working pressure obtained, as just explained, we find the total pressure on the piston.

Now multiply the number of strokes performed in a minute by the actual length of each, and we shall thus learn the space traversed by the piston in feet. Multiplying this by the total pressure, and dividing by 33,000, we have the actual horse-power.

The rule for calculating this should be carefully remembered, as it is often required, and it may be simply expressed in the following form:—

From the pressure of the steam, expressed in pounds per square inch, deduct $1\frac{1}{2}$ pounds for loss, and multiply the area of the piston in square inches by the remainder; then multiply this amount by the space travelled by the piston per minute expressed in feet, and divide by 33,000; the quotient will be the actual horse-power.

An example will render this perfectly plain. Let us suppose an engine whose piston has an area of 200 square inches, and the length of whose stroke is two feet. Further, let it make sixty complete strokes or double movements of the piston per minute, and let the pressure of the steam be twelve pounds per square inch. What is its actual power?

The pressure exerted on the piston by steam in this case is $200 \times 10\frac{1}{2}$, or 2,100 lb., and the space travelled over by the piston in each minute is 120×2, or 240 feet. The work accomplished, therefore, is $2{,}100 \times 240 = 504{,}000$ foot-pounds, and the horse-power, therefore, is $\frac{504{,}000}{33{,}000}$, or a little over 15. If in any of these cases the vacuum in the condenser is imperfect, there is a corresponding pressure opposed to that of the steam, and this must be allowed for in calculating the power.

The nominal power is, as we have said, an arbitrary expression, and is nearly always considerably below the actual power, being often as low as from a fourth to an eighth of it.

The formula usually employed for calculating this is known as the Admiralty rule, and is as follows, $\frac{d^2v}{6000}$, where d is the diameter of the piston expressed in inches, and v the velocity of the piston expressed in feet per minute.

We can now apply this rule to the case just given, but must first ascertain the diameter of the piston, and since its area is 200 square inches, this is about 16 inches. The formula $\frac{d^2v}{6000}$ therefore becomes $\frac{16 \times 16 \times 240}{6000} = \frac{6144}{600} = 10\frac{1}{4}$ nearly.

This, then, is the nominal horse-power of the engine.

The same term is frequently applied to a boiler as expressive of its size and capabilities; but it is very evident that in this case its meaning is somewhat different. An engine of one horse-power will, as we have seen, exert a force equivalent to raising 33,000 lb. a foot high per minute. In an hour, therefore, it would raise nearly 2,000,000 lb. to the same height. Now we have seen that the evaporation of a cubic inch of water exerts a force equivalent to raising a ton a foot high; to raise the 2,000,000 lb., therefore, will require the evaporation of nearly 1,000 cubic inches of water. A considerable portion of the force thus produced is, however, employed in moving the engine itself, and wasted or lost in various other ways, so that a much larger quantity of water must be evaporated by the boiler to accomplish the amount of work required.

Allowing for all these sources of waste, engineers calculate that as a general rule a boiler should evaporate one cubic foot of water per hour for each horse-power of the engine. This is therefore taken as the standard; and thus, when a boiler of 50 horse-power is spoken of, we at once understand that one is meant which is, under ordinary circumstances, capable of evaporating fifty cubic feet of water per hour.

There is a small but very important piece of apparatus that is frequently attached to one end of the cylinder of an engine, and known as the "indicator," to which we must here refer. The pressure of the steam in the cylinder is often very different from that in the boiler, as the size of the steam-pipes and ports considerably modify it. We require, therefore, in order to tell accurately the power of the engine, some means of ascertaining the pressure in the cylinder during the stroke. The vacuum in the condenser may likewise become imperfect, owing to the air-pump being out of order, or from some other cause, and we want in some way to be apprised of the fact. Both these ends are accomplished by means of the indicator, which is shown in Fig. 34. It consists of a brass cylinder, a, some ten or twelve inches long, and about two inches internal diameter; it is very truly turned inside, and has a solid piston or plunger, b, fitting it accurately. To the upper extremity of the piston-rod a pencil, g, is firmly fixed, so as to record on a card suitably placed the movements of the piston. At the lower end a screw is cut, by which it is usually affixed to the upper end of the cylinder, a stop-cock, e, being placed so as to cut off the communication when it is not required to use the instrument; a spiral spring is fixed to the piston, b, and at the upper end to a ring or fastening, c, fixed in a suitable position; this is so arranged that when the spring is in its normal state, the piston is about the middle of the cylinder. The spring can, however, be compressed or extended. A card, f, is mounted in a frame placed above the indicator, and made to move backwards and forwards with the motion of the piston. This is usually accomplished by a cord passing round a pulley, and fastened to some convenient part of the engine. This cord pulls the card one way, and as soon as the motion of the piston is reversed, a spring or weight brings it back to its original position. When the stop-cock, e, is closed, the pencil is at rest, and a horizontal line is therefore traced on the card as it moves to and fro; but as soon as the steam is allowed to enter the indicator, the pencil moves up and down, and a figure is traced on the card which indicates to an experienced eye the action of the engine.

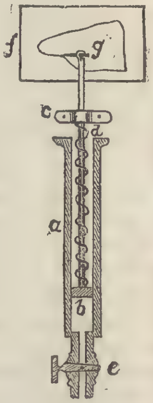


Fig. 34.

Let e be turned on just as the steam is admitted to the upper end of the cylinder, the piston b will be immediately forced up, and trace an almost vertical line; the full pressure is not, however, instantly attained, and hence the line continues for

a little way to slope upwards. If the steam is cut off at a third, or any other portion of the stroke, the line immediately tends downwards, and by its rapid fall indicates the decreasing pressure, until the piston arrives at the lower end of the cylinder.

The upper end is now put into communication with the condenser, and if the vacuum there be good, it will be indicated by a sudden fall in the curve. The pressure of the air being allowed to act freely on the upper side of the piston, it will by this be depressed below the normal line, the spring being extended by the pressure, and the lower the piston sinks the more perfect does it show the vacuum to be. It is comparatively easy to graduate the card so as to show at a glance the exact pressure, and also the degree of vacuum in the condenser; and the further these extremes are removed from one another, the greater is the power of the engine. We may, in fact, obtain a general idea of its action from the area of the figure traced on the card; for the larger this is, and the more closely approaching to a parallelogram, the more perfect is the action of the engine.

Apart from showing in this way the power, the indicator diagram is of very great service in showing the action of the valves. If, at the extreme right of the figure, the line descends but slowly, it clearly shows that the communication with the exhaust is made too slowly, or else that condensation does not proceed with sufficient rapidity. The more vertical the line is here, the better is the action of the condenser. The ascending stroke at the other end of the card should likewise be nearly vertical; but to an experienced engineer each corner of the diagram will indicate some peculiarity in the action of the "lap" or "lead" of the valve, and thus enable him at once to point out and rectify any defects. We can, however, only just point out the broad principle of this very valuable piece of mechanism, and for full details must refer the student to some of the various works that inquire fully into the indicator and the indicator diagram.

AGRICULTURAL DRAINAGE AND IRRIGATION.—VIII.

By Professor WRIGHTSON, Royal Agricultural College, Cirencester.

SEWAGE IRRIGATION.

THE sewage question is interesting and important from two aspects: first, because it touches the sanitary condition of the country; and, secondly, as an agricultural problem. The pollution of our rivers has been the first and most distressing effect of a large population and a defective sewage system; and the loss of an immense mass of valuable fertilising material has been the second, although less urgently pressing, inducement to action. Hence the sewage question claims attention alike from town and country; and it is not surprising that every intelligent person throughout the kingdom should be more or less interested by it. The problem is simplified by the admirable manner in which the agricultural requirements meet those of a more purely sanitary character. If the rivers cry out against an influx of filth, the land calls as loudly for material to restore its waning fertility; hence, both the land and water are grateful when sewage is diverted from the rivers and poured over the fields. Time is required to show how far such a system can be generally and successfully applied. The soil possesses a wonderful deodorising and decolorising power, and filthy water, after having passed through a layer or filter of earth, comes forth more or less purified. Soil has also been shown, of late years, to be capable of removing some of the most important elements of fertility from solution, and holding them until they are required as plant-food. This power is not yet fully understood, but it is supposed to resemble that possessed by woollen cloth for fixing colouring matter used in dyeing, or the power by which charcoal acts in purifying sugar. Hence, soil is well calculated both to render sewage innocuous, and to conserve its valuable fertilising qualities. The only questions are: How far these powers possessed by soils are likely to be persistent in any particular case? how far the produce of such land will continue to be wholesome? and how far the sewage will continue to flow from the area devoted to it as a *pure* stream? We are thus introduced to the subject of "sewage irrigation," offering, as it does, a simple solution to an important national question. Divert the streams of sewage from their course towards the neighbouring river; construct a series of water-meadows, or fields for cultivation, laid out upon a similar principle, and allow the fertilising flood to expand over their surface; let the purified water again be collected by ditches and discharged into the river at a lower level. Such is the simple plan proposed, and in many cases carried out with success, up to the present time.

Before entering more into detail with reference to cases in which this principle has been adopted, I shall point out the advantages it presents over rival systems for utilising sewage. It deals with sewage *as it is*. There seems to be little reason for expecting that the population of this country will abandon the water-closet. Earth and ashes may in country places be advantageously substituted for water, as has been shown by the Rev. H. Moule, but such a plan is not likely to meet with favour in towns, and appears impracticable for such gigantic centres of population as London, Birmingham, and Liverpool. If it be granted that water will continue to be the vehicle for carrying away urban *excreta*, then we have irrigation as the sole means by which it can be advantageously applied. Schemes have indeed been proposed by which the valuable matter contained in sewage, as well as the deleterious and offensive matter associated with it, should be precipitated, collected, dried, and used as a manure, while the water, freed from its impurities, should then flow harmlessly on its course. Feasible as such a proposal may at first sight appear, it is beset with difficulty. The value of sewage does not depend upon its filthiness, but upon certain ingredients which occur in very small quantities. Robbed of these, the sewage water would be valueless, and any system of sewage utilisation, on the principle of precipitation, must provide that these valuable ingredients be arrested in the precipitated mass. This, however, is a difficulty which appears insurmountable. First, because these valuable ingredients—ammonia and potash—are exceedingly loth to quit their soluble condition under any circumstances, and especially when mingled with such a mass of water as in town sewage. The consequence is that, precipitate as you like, or with what you please, the ammonia and potash will flow away in the "purified" water, and the remaining mass, whether it be named A B C or X Y Z, will be of small fertilising value. From these considerations it is evident that as yet no plan based upon the principle of precipitation is likely to succeed, and that irrigation is the only alternative.

We have, then, to do with an immense mass of sewage, the character of which we must very briefly consider. Sewage consists of the entire water-supply of our towns after it has been used for domestic purposes, of the excreta of man and animals, of the rainfall of the town area, and of earthy matter washed and worn from the streets. It contains valuable fertilising matter in an extremely dilute condition. This can be demonstrated by analysis, and many eminent chemists having examined town sewage at various times, have given us a tolerably accurate idea of its composition. Phosphoric acid, nitrogen, and potash, are the three principal ingredients of agricultural importance. These substances can be purchased in the form of guano, "superphosphates," potash salts, and other manures; and since these substances are marketable, an estimate can readily be formed as to the cheapest rate at which they may be obtained. Thus, it may be shown that ammonia may be purchased in the form of some manurial substance at the rate of, say, £60 per ton. Hence, a commercial value may be attached to the three substances above mentioned, and by finding the proportion in which they exist in town sewage, an estimate may be formed as to its value. It is needless here to enter further into detail, and it is sufficient to state that the value of sewage calculated upon purely chemical grounds is 1·8d. per ton, varying, of course, according to season and other conditions. The result of sewage irrigation agrees closely with this estimate, being more usually below than above it. Thus, in the case of Rugby, where the effects of sewage were closely watched by a Royal Commission, the Commission lost money upon the sewage, contracted for at 1d. per ton. On the Barking Creek farm the result of sewage application was approximately that 100 tons of sewage yielded 1 ton of grass, and if this were worth 10s., then 100 tons yielded 10s., or at the rate of 1·2d. per ton. It is only fair to state that Mr. Mechi, who converts the whole of his farm manure into the liquid form, obtains very

superior results to those just given; but it must be remembered that Mr. Mechi has perfect control over the composition of the liquid manure used at Tiptree, which is, probably, frequently more concentrated than town sewage. Also, at Tiptree the liquid dressing is applied *when it is required;* whereas in the utilisation of town sewage it is necessary to pour the water over the land at all seasons, whether required or not. We have, then, to do with a substance of trifling value per ton, although of high value when we reflect upon its immense quantity. The question is therefore as follows: How is a substance valued at from 1d. to 2d. per ton to be economically applied to the land? How can we carry such a *worthless* material for miles into the country, and apply it for purposes of cultivation? The answer is simple. It cannot be applied advantageously where any appreciable cost per ton must be incurred. Pumps, expensive pipes, and business expenses, are serious difficulties in sewage application, and success will probably only ensue where *gravity* is the sole force for conveying the sewage to its destination. The estimated value of sewage depends upon chemical analysis, and upon results obtained at Rugby and elsewhere from its use. Both methods, however, fail in precision: the first, because the value of the water as an essential element in the development of plants is not considered; and the second, because the sewage has never been applied under conditions calculated to bring out its maximum effects. Could the use of sewage be restricted to seasons of the year when water is most needed, and could it then be applied to plants capable of making the greatest use of it, results far superior to any yet recorded might be obtained. It is, indeed, probable that the success attending liquid manuring at Tiptree and elsewhere may be thus accounted for, as in such cases thorough control can be exercised. In dealing with the drainage of a large town, *storing* the sewage cannot be contemplated. At the same time much may be done towards its profitable application by so dividing the fields over which it flows, that crops may be grown requiring it at different periods. This has been done with success at Barking Creek farm, where rye-grass, cereals, flax, mangold, strawberries, etc., are very successfully cultivated with the aid of sewage.

I shall now mention a few cases in which the drainage of towns has been used for irrigating land. Edinburgh offers one of the oldest examples. There the sewage is allowed to flow over a tract of about 300 acres, with good results *per acre*, but the amount realised per ton of sewage is difficult to estimate, on account of the vast mass of water employed. The produce per acre per annum is from £20 to £30 worth of grass, sold to the cow-keepers of the city. The quality of the land is exceedingly poor, being little better than sand, a fact which has given countenance to the scheme of the Essex Reclamation Company for pouring the sewage of North London over the Maplin Sands. It is worthy of remark, that immense as is the mass of water used per acre in the case of the Edinburgh meadows, any attempt to enlarge the area of irrigated surface has been attended with a diminished yield over the remainder. Another curious fact is, that although sewage is capable of raising large crops of grass, the fertility of the soil does not appear to be increased. This fact has been pointed out by Messrs. Lawes and Gilbert, in their experiments at Rugby, where land, which had produced large crops under the influence of sewage, immediately fell back to its old standard of productiveness when the supply of sewage was withdrawn. The authorities just named made a series of experiments upon the use of sewage in the neighbourhood of Rugby. They employed the large quantities of 3,000, 6,000, and 9,000 tons of sewage per acre respectively, upon contiguous plots, and found that each additional quantity was followed by an increase of crop, although the amount of grass per 100 tons of sewage used was less in the case of the heavy dressing. This, taken in connection with a similar result obtained at Edinburgh, is interesting, as showing the large amounts of this material which may be advantageously applied to land. Further, at Rugby it was found that although a large quantity of grass was grown, the quality of the herbage suffered under the system of sewage irrigation.

The utilisation of the Croydon sewage has very often been cited as a successful enterprise. In this instance, sanitary considerations have been the chief inducement to action, and the writer will never forget one proof that, from this point of view the success has been most complete. On a hot day in July he arrived at Beddington, and was kindly received by Mr. Marriage, the lessee of the irrigated land. Among other refreshment, two bottles were placed upon the table, the one containing a wine, the other a colourless fluid (not whisky), which was neither more nor less than purified *sewage*. It appears that visitors to the irrigated fields are given the choice between wine and a sample of purified sewage, in order that they may thus test the complete success of the process used. The appearance of the liquid and the absence of smell betokened the removal of all unwholesome matter. The sewaged fields at Croydon yielded a rent of £5 per acre to the lessors in 1868, but the old lease was then just falling in. Italian rye-grass was the crop exclusively grown, and this required frequent renewal, as in a year or two its place was usurped by "water-grass." Frequent re-sowings have also been found necessary at Barking Creek farm. During the dry season of 1868 I was informed that the irrigated lands at Beddington suffered from the drought, although supplied with an almost unlimited amount of water. Here the sewage alternately spreads over fields, and is collected by ditches three times in succession, after which it flows into the river. The exit of the stream of purified sewage is periodically inspected, and the condition of the water reported upon.

In the foregoing remarks upon sewage irrigation the subject has been treated very generally. The mass of published statistical information is exceedingly large, and in order to enter into details much more space would be necessary than is here allotted to the subject. The object of the writer has therefore been to introduce as many interesting facts as possible in connection with a subject which, in the preceding short essay, has been little more than outlined.

PRACTICAL PERSPECTIVE.—VII.

HITHERTO all the planes and objects delineated have been supposed to be so placed that some of their lines are parallel, and others at right angles to the plane of the picture.

We now enter upon the system by which perspective projections are made when the sides of the plane or object recede from the picture at angles other than right angles.

Reverting to Fig. 4 (Vol. I., page 293), it will be remembered that the triangle E C F was supposed to be laid down so that the points G and H were obtained on the horizontal line; and these represented the true distance of the spectator from the picture.

In the system now under consideration, a similar triangle, A C B, standing on the line A B, is supposed to be laid down below or above the horizontal line; and this will give the point I, the station-point of the spectator. The line I D is then called the *line of direction*, as indicating the direction of the central ray, or axis of the cone of rays.

With this brief introduction, it will, it is hoped, be found possible for the student to follow the lessons. These are most carefully graduated, not merely according to theory, but from *absolute practice* in teaching. We will therefore at once proceed to

Fig. 34.—Here, having drawn the picture-line and the horizontal line, and having fixed the centre of the picture and the line of direction, the length of which is determined by the distance of the spectator from the picture, draw a horizontal line at S. Thus far for the height and distance of the spectator.

The next question is this—What angles do the sides of the object make with the picture-plane?

This must, of course, depend on the plan given in Fig. 35.

Here E F is the base-line, or line on which the picture-plane is to stand; and the square A B D C is the plan of the plane to be put into perspective.

From this it will be seen that the angle F A B is one of 40°, and the angle E A C one of 50°, with the plane of the picture.

Returning now to Fig. 34, and having drawn a line at S parallel to the picture-line, on each side of the point S construct angles corresponding with the angles which the lines of the plan make with the line E F—viz., G S H and I S J. In this case these angles are known to be 50° and 40°; but as a rule, if a plan be given, the angles at the station-point may be constructed similar to those of the plan by the method shown in Fig. 18 of "Practical Geometry applied to Linear Drawing" (Vol. I., page 124).

Produce the lines S H and S J until they meet the horizontal line; and these points of meeting are called the *vanishing*

points for these lines. Call the one V P 1 (vanishing point No. 1), and the other V P 2.

From V P 1, with radius V P 1 to S, describe an arc, cutting the horizontal line. Call this intersection M P 1 *(measuring point* No. 1). From V P 2, with radius V P 2 to S, describe an arc, cutting the horizontal line in M P 2 (measuring point No. 2).

Now it will be remembered that when in former studies a line was supposed to be receding from the picture-plane at right angles to it, and it was required to cut off a certain portion of that line, or to mark a particular point upon it, the real length to be cut off was marked on the picture-line, and a line was drawn to the point of *distance,* intersecting the original line in

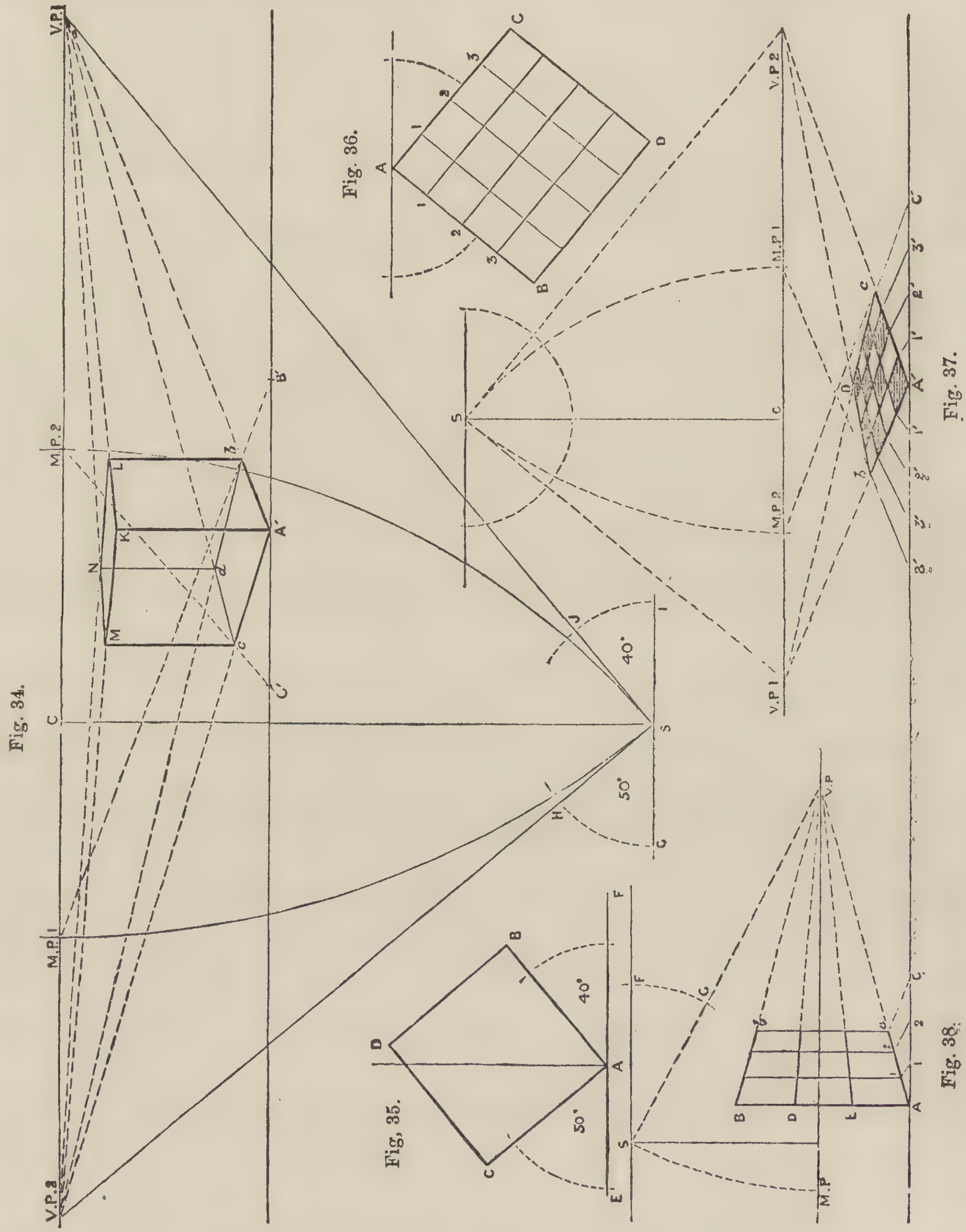


Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

The reason why these points are called *measuring* points will be understood when their use in measuring is seen as we proceed.

All the points necessary for our present purpose having been fixed, we can now proceed with our perspective projection.

Having fixed that the angle A of the plan shall be at A′ on the picture-line, draw a line from A′ to each of the vanishing points.

a point required. In the present system of perspective, *the measuring points are used for this purpose,* as will be seen by the following process :—

From A′ set off on the picture-line the length A′ B′ and A′ C′. equal to A B and A C, the sides of the plan. From B′ draw a line to the measuring point belonging to the vanishing point to which the line which is to be cut off is drawn. Thus the line we are now considering is drawn from A′ to V P 1; therefore,

from B′ draw a line to M P 1, which cutting the line A′ V P 1, gives the intersection *b*, which is the point required; and A′ *b* is the perspective representation of the line A B of the plan when receding at 40° from the picture.

Similarly, draw a line from A′ to V P 2; and from C′ draw a line to M P 2, cutting A′ V P 2 in *c*. Then, as in the former case, A′ *c* is the perspective representation of the line A C of the plan.

It is here necessary to bear in mind a short rule—viz., *all lines which in the object are parallel to each other vanish in the same point.*

Now, on referring to the plan, it will be seen that the line B D is parallel to A C, and that the line C D is parallel to A B.

Therefore, in the perspective projection, these lines will vanish in the same points.

From *b* draw a line to V P 2, and from *c* draw a line to V P 1.

These lines intersecting in *d* (which corresponds with D in the plan) will give A′ *b d c* as the perspective representation of the plane A B D C when placed at the angles of 40° and 50° to the picture-plane.

Let us take Fig. 35, however, to be not a *single plane*, but the plan of a cube, the faces of which are at the stated angles to the picture-plane.

Then, having projected the plan already shown, erect a perpendicular at A′—viz., A′ K. This perpendicular is to be the *real* height of the foremost edge of the object, whatever that may be. But as in this case a cube is the subject of the study, the edge A′K will of course be equal to any one of the edges of the plan—viz., A B, A C, B D, or C D.

Now the upper edges of the cube are parallel to the lower ones, and therefore they will vanish to the same points.

Therefore from K draw lines to both vanishing points.

From *b* and *c* draw perpendiculars cutting the lines drawn from K in L and M.

From L and M draw lines to V P 1 and V P 2, and these, intersecting in N, will complete the representation of the cube.

It will prevent the student experiencing much disappointment in his results if he bears in mind that when the angle on each side of the station-point has been constructed, the space contained between these two angles should correspond with the angle of the object itself; thus, when an angle of 50° has been constructed on the one side of S, and an angle of 40° on the other, then the angle J S H remaining between them should be the angle of the object, which in the present instance is a right angle.

It is also necessary to point out when a rectangular object, such as a cube, stands at equal angles to the picture-plane—that is, when it recedes on each side at 45°—the points of distance become the vanishing points.

Fig. 36.—In this figure the rule, that "all lines which in the object are parallel to each other vanish in the same point," is plainly illustrated.

Here the subject is a square, divided into smaller squares by lines parallel to the sides.

Having drawn the picture-line, horizontal line, and line of direction, find the vanishing points and measuring points, as in the former case; it has already been stated that the station-point may be taken below or above the horizontal line. The latter is chosen in the present study.

The angle A of the plan (Fig. 37) being fixed at A′, draw lines to the vanishing points.

From A′ set off A′ B′ and A′ C′ equal to the sides of the square, and from these points draw lines to the measuring points, which, cutting the lines drawn to the vanishing points, will give the points *b* and *c*, completing the perspective view of the external square.

Set off on the picture-line between A′ and B′ and A′ and C′ the points 1′, 2′, 3′, corresponding with those similarly figured in the plan. From 1, 2, 3 draw lines to the measuring points, cutting A′ *b* and A′ *c*, and from such intersections draw lines to the vanishing points, which, crossing each other, will divide the square as required, and will thus complete the perspective representation of the original figure.

Fig. 38.—This is another adaptation of the same study, and gives the principles on which windows, doors, etc., in buildings standing at an angle to the picture, are drawn.

The height of the spectator and the distance having been fixed, let us suppose that the angle at which the plane is to be represented is that shown at S—viz., F S G.

Produce S G until it cuts the horizontal line in V P. From V P, with radius to S, describe an arc, cutting the horizontal line in M P.

Draw A B, the vertical edge of the plane to be drawn, and from its extremities draw lines to the vanishing points.

From A set off A C equal to the width of the plane, and draw a line to the measuring point, which, cutting A V P in *c*, will give the plane for the distant vertical side *c b*.

Now on A B set off the required points of division, E and D, and from these draw lines to the vanishing point, which will divide the plane into three strips, which, if it were parallel to the plane of the picture, would be horizontally placed.

Between A and C set off the points 1, 2, representing the widths into which the plane is divided vertically, and from these points draw lines to the measuring point, cutting A *c* in 1, 2; on these erect perpendiculars, which will complete the figure.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

X.—GALILEI GALILEO.

BY JAMES GRANT.

GALILEI GALILEO, the inventor of the telescope—one of the most distinguished of Italian philosophers—was born in the city of Pisa, about the year 1564. His father, a Florentine noble, had him educated for the profession of medicine; but a love for geometry inspired him, and to this study he turned all the powers of his mind. The writings of Archimedes and Euclid he mastered without the aid of a tutor; and so great were his acquirements, that in his twenty-fifth year he was appointed by Cosmo II., then Grand Duke of Tuscany, to the mathematical chair in Pisa. Before three years were passed he had to quit that city, his sturdy opposition to the philosophy of Aristotle having gained him many enemies; so he accepted the professorship of mathematics in the then famous University of Padua, where for eighteen years his name adorned it, and he succeeded in developing a high taste for the physical sciences.

Galileo had distinguished himself by no discovery (a few minor contrivances excepted) till he attained his forty-fifth year. This was in 1609, when he produced a telescope; and perhaps no invention that science has presented to mankind is so boundless in its influence, and so extraordinary in its nature, as that long glass by which distant objects are viewed clearly. It chanced that in 1609—the same year in which Kepler published his "Commentary on Mars"—Galileo was in Venice, when, in the course of conversation, he heard it stated that "a Dutchman, named Jansen, had constructed and presented to Maurice, Prince of Nassau, an instrument through which he saw distant objects magnified and rendered so distinct that they seemed close to the observer." Struck by this story, which a few believed and many discredited, the mind of Galileo became filled with the importance of such an instrument; and so thoroughly had he already studied the entire science of lenses, that he not only discovered the principle of their application in a shifting tube, but was speedily able to make a telescope for his own use. To the uninstructed mind the power of seeing clearly objects at a vast distance brought close and nigh apparently, must seem miraculous; and hence it was that the Arabs, whom the officers of Colonel Malcolm's force in Persia permitted to look through their telescopes, fled in terror, exclaiming, "You are magicians! Now we see how you take towns; that thing, be they ever so far off, brings them as close as you like." It was an invention valuable alike for peace and war; but to have been the first astronomer in whose hands so valuable a gift was placed, was an eminence to which Galileo owed all his reputation and future persecution.

As soon as his telescope was complete he applied it to the stars of the firmament, and on the night of the 7th of January, 1610, when first he used it, he saw close to Jupiter three little bright stars, hitherto unseen by human eye, lying in a line parallel to the ecliptic, two to the east and one to the west of the planet. Then a great emotion of enthusiasm is said to have filled his heart; but regarding them as merely ordinary stars, he never thought of estimating their distances. But on the night of the 8th of January, when again regarding Jupiter, he

was surprised to see all the three stars to the west of the planet. It was requisite that the motion of Jupiter should be direct to produce this effect, whereas it was distinctly retrograde. On the 10th he could distinguish only two stars to the east of the planet, the motion of which he was quite unable to explain. He ascribed the change to the stars themselves, and on the night of the 11th he no longer doubted that he had discovered three planets that revolved round Jupiter; and on the 13th he saw, for the first time, the greater planet's fourth satellite.

This discovery cast a new light on the entire celestial system. Hitherto it had been believed that while this earth was the only planet favoured with the existence of a moon, it was of necessity the only one in the universe that was habitable, and as such occupied pre-eminence in being the centre of the system; but the discovery of *four* moons revolving round a much nobler planet than ours, deprived the old argument of all force, and established a new analogy to it and the other heavenly bodies.

In 1610 Galileo, in his "Sidereal Messenger," announced his great astronomical discovery to the then very limited world of science. Kepler perused it with the deepest interest; for while it confirmed and extended his own brilliant discoveries, it dispelled the old illusions of past philosophy; and in the "Dissertation" which he published on the discovery of the learned Pisan, he expressed a hope that similar satellites might be traced around Mars and Saturn. Galileo next applied his wonderful glass to the study of Venus, and in 1610 discovered in the phases of that planet the forms of waxing and waning peculiar to the moon. He next detected the spots on the face of the sun, ascribing them to the rotation of the central luminary; and on the surface of our moon he saw her valleys in shadow, her mountains in light, and determined the curious fact of her balance or trepidation in the firmament, in virtue of which parts of her shining disc occasionally appear and disappear.

It was while thus occupied in his native city of Pisa—to which he had been recalled by the Grand Duke Cosmo, ever his generous patron, that he might pursue his astronomical studies—that the fame of his discoveries spread over all Europe, and many learned men, who had been obstinate adherents of more ancient systems, felt themselves compelled to acknowledge the truth of the new. But Galileo, though ambitious of propagating the new truths which he wished to establish as to the working of the solar system, had mistaken the general disposition of mankind, and the narrow prejudices of the age in which he lived. "That same system of the heavenly bodies which had been discovered by the humble ecclesiastic Nicholas Copernicus, which had been patronised by the kindness of a bishop, published at the expense of a cardinal, and which the Pope himself had sanctioned by the warmest reception, was, after the lapse of a hundred years, doomed to the most violent opposition as subversive to the Christian faith. On no former occasion had the human mind exhibited such a fatal relapse into intolerance." So the clergy became the most bitter opponents of Galileo, and were resolved to persecute him even unto death, if possible, becoming for the time thorough barriers to the progress of science.

Thus in the year 1615, in consequence of complaints laid before the Holy Inquisition, Galileo was summoned to Rome, that he might answer for the foul heretical opinions he had promulgated verbally and in writing. He was charged with "maintaining as true the false doctrines held by many, that the sun was immovable in the centre of the world, and that the earth revolved with a diurnal motion; with having certain disciples to whom he taught this false doctrine; with keeping up a correspondence on the subject with several German mathematicians; with having published letters on the solar spots, in which he explained the same false doctrine as true; and with having glossed over with a false interpretation those passages of the Scripture which were urged against it."

In February, 1616, the consideration of these charges came before a meeting of the Holy Office, and the court avowing their desire to deal gently with the prisoner, issued the following decree: —"That his Eminence Cardinal Bellarmin should enjoin Galileo to renounce entirely the above cited false and heretical opinions; that on his refusal to do so he should be *commanded* by the Commissary of the Inquisition to abandon the said doctrine, and to cease to teach and defend it; and that if he did not obey this command he should be thrown into prison."

Galileo appeared before Cardinal Bellarmin on the 26th of the same month, and after receiving from him some gentle admonitions, the Commissary, in pursuance of remit made to him, commanded the astronomer, in presence of a notary and certain witnesses, to abstain altogether from the diffusion of his erroneous opinions, as it was now unlawful for him to teach them in any way whatever, either orally or in writing. To these absurd injunctions Galileo was compelled to promise obedience, and was passed through the perilous gates of the Inquisition. To the influence of the Grand Duke Cosmo, and many other Tuscans of high rank, the mildness of this sentence must be ascribed. Nor was the Papal Court itself without many high ecclesiastics who took a deep interest in the trial of one who was by most men considered as the pride of Italy. However, so great was the dread of the officials of the Holy Office that he might not be deterred by threats from propagating his obnoxious doctrines concerning the motion of the earth round the sun and so forth, that a stern decree was issued denouncing them as false, contrary to the writings of the Fathers, and prohibiting the sale of every book in which they should be maintained.

Returned now to the Tuscan capital, Galileo resumed his studies with undiminished ardour; but his recantation was so formal and without reservation, that prudence might have restrained him from bringing them unnecessarily before the world, and, more than all, his clerical persecutors. No decree had been issued against his telescope, his scientific discoveries, or the free exercise of his genius. He was simply forbidden to teach a doctrine deemed injurious to implicit belief in the Scriptures, and to the Christian faith. Moreover, he was liable to the authority of a court which possessed the power of torture and of death by fire within its jurisdiction.

But his enthusiasm in the cause of science was irrepressible, and rendered him fearless as to consequences. Thus, before six years were past, he began to compose his "Cosmical System; or, Dialogues on the Two Greatest Systems of the World—the Ptolemean and the Copernican," a work, the concealed object of which was to establish the very opinions he had promised, under threats, to abandon. Three speakers, Sagrado, Salviatus, and Simplicius, debate on the merits of those systems, and thus Galileo hoped that by this indirect mode of diffusion he might get the better of the Holy Office. So the work was printed at Florence in 1632.

A year elapsed before the Fathers of the Holy Office gave any indication of an attempt to open their prosecution again. Nor, to do them justice, did they seem to care for doing so, until they saw that those tenets, to them so obnoxious, were spreading fast, in consequence of the publication of the imaginary dialogues. A careful examination soon proved the work to be a deliberate violation of the injunctions laid upon Galileo, whom they summoned once more before their tribunal in 1633, and the poor old man, now in his seventieth year, was compelled to travel from Arcetri to Rome, at a time when the appliances for locomotion were not what they are now; and on his arrival he was committed immediately, like a criminal, to the chambers of the Fiscal of the Inquisition. The friendship and influence of the Grand Duke obtained a change for him, and he was permitted to reside in the palace of the Tuscan ambassador during the two months over which his trial extended. Examined on oath before that dread and mysterious tribunal, he candidly acknowledged that he was the author of the Dialogues, and that he had composed them in such a manner "that the arguments in favour of the Copernican system, though given as partly false, were yet managed in such a mode that they were more likely to confirm than overthrow its doctrines; but that this error, which was not intentional, arose from the natural desire of making an ingenious defence of false propositions and of opinions that had the semblance of probability."

Such was his simple confession. For defence he could produce only the certificate of Cardinal Bellarmin, which omitted all allusion to the non-teaching of the Copernican doctrines. This was deemed by the Holy Inquisition to be but an aggravation of the crime, and they proceeded to pronounce a sentence, or rather, under terror of death, to extort a confession perhaps one of the most memorable in the history of the human heart.

After solemnly invoking the name of our Saviour, they declared that Galilei Galileo had become a heretic by believing in a doctrine contrary to the Scripture, "that the sun was the

centre of the earth's orbit, and did not move from east to west; and by defending, as probable, the opinion that the earth moved, and was not the centre of the world, and that he—the said Galileo—had thus incurred all the censures and penalties enacted by the Church against such offences; but that he should be absolved from these penalties, provided he abjured and cursed all the errors and heresies contained in the formulæ of the Church, which should be submitted to him; that he should be condemned to the prison of the Inquisition during pleasure, and that during the three following years he should recite the seven penitential psalms."

Seven cardinals subscribed this astonishing sentence on the 22nd of June, 1633.

Then Galileo, worn with age, weary of the mental torture to which he had been subjected, and weakened by the influences around him, signed an abjuration, alike humiliating to himself, and degrading to philosophy. In his old age, with hair and beard as white as snow, bent on his knees, with his right hand resting on the New Testament, Galileo avowed that he abandoned, "as false and heretical, the doctrine of the earth's motion, and of the sun's immobility, and pledged himself to denounce to the Holy Office any other person who was suspected of such heresy."

It seemed as if the hand of Fate was over the unhappy Galileo now. Freed from the Inquisition and all its terrors, he only returned home to find calamity there, for his favourite daughter had been seized with an illness which soon ended in death. Intense melancholy, hernia, palpitation of the heart, and a perfect loss of appetite now fell upon himself, all of which was believed by his enemies to be the curse of God upon him as a heretic; and though he prayed for leave, impoverished though he was, to visit Florence in search of medical advice, it was refused him by the Holy Office, which had special supervision of his movements. The Pope, however, took mercy upon him, and in 1638 he was permitted to visit the Tuscan capital, in care of his friend Padre Castelli and a familiar of the Inquisition, an indulgence soon withdrawn, and he was ordered to return to Arcetri. His eyesight had now begun to fail him, and in the year 1637 he became stone-blind.

Even the Inquisitors now had mercy on the patriarch of science, aged, blind, bereaved, impoverished, and crushed in spirit. They permitted him to have the society of his friends, who now thronged about him to express their admiration and sympathy. Among those who came thus were the reigning Grand Duke of Tuscany, Pierre Gassendi, the great French philosopher and mathematician, John Milton, the author of "Paradise Lost," Diodati, and many more. His sense of hearing soon followed his sight; but the brilliant faculties of his mind remained unimpaired; and it was while occupied in experiments, and in considering the force of percussion, that a fever and palpitation of the heart fell upon him, and he expired on the 8th of January, 1642.

PRINCIPLES OF DESIGN.—XIII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

Having considered furniture, the formation of which requires a knowledge of construction, or of what we may term structural art, we pass on to notice principles involved in the decoration of surfaces, or in "surface decoration," as it is usually called. Under this head, we commence by considering how rooms should be decorated; yet, in so doing, we are met at the very outset with a great difficulty, as the nature of the decoration of a room should be determined by the character of its architecture. My difficulty rests here. How am I to tell you what is the just decoration for a room, when the suitability of the decoration is often dependent upon even structural and ornamental details; and when, in all cases, the character of the decoration should be in harmony with the character of the architecture? Broadly, if a building is in the Gothic style, all that it contains in the way of decoration, and of furniture also, should be Gothic. If the building is Greek, the decorations and furniture should be Greek. If the building is Italian, all its decorations and furniture should be Italian, and so on.

But there are further requirements. Each term that I have now used, as expressive of a style of architecture, is more or less generic in character, and is therefore too broad for general use. What is usually termed Gothic architecture, is a group of styles having common origin and resemblances, known to the architect as the Semi-Norman or Transition style, which occurred in the twelfth century under Henry II. (it was at this time that the pointed arch was first employed). The Early English, which was developed in the end of the twelfth and early part of the thirteenth century, under Richard I., John, and Henry III.; the Decorated, which occurred at the end of the thirteenth, and early portion of the fourteenth century, under Edward I., Edward II., and Edward III.; the Perpendicular, which occurred at the latter part of the fourteenth, and through the greater portion of the fifteenth century, under Richard II., Henry IV., V. and VI., Edward IV. and V., and Richard III.; and, lastly, the Tudor, which occurred at the end of the fifteenth, and the beginning of the sixteenth century, under Henry VII. and Henry VIII. All these styles are properly spoken of as one, and are expressed by the one term—Gothic. It is so also, to an extent, with the Greek, Roman, and Italian styles, for each of these appear in various modifications of character, but into such details we will not enter; it must suffice to notice that the character of the decoration must be not only broadly in the style of the architecture of that building which it is intended to beautify, but it must be similar in nature to the ornament produced at precisely the same date as the architecture which has been employed for the building.

It must not be supposed that I am an advocate of reproducing works, or even styles of architecture, such as were created in times gone by, for I am not. The peoples of past ages carefully sought to ascertain their wants—the wants resulting from climate—the wants resulting from the nature of their religion—the wants resulting from social arrangements—the wants imposed by the building material at command. We, on the contrary, look at a hundred old buildings, and without considering our wants, as differing from those of our forefathers, take a bit from one and a bit from another, or we reproduce one almost as it stands, and thus we bungle on, instead of ever seeking to raise such buildings as are in all respects suited to our modern requirements.

Things are, however, much better in this respect than they were. Bold men are dealing with the Gothic style in its various forms. Scott, Burgess, Street, and many others, are venturing to alter it; and thus, while it is losing old characteristics, and is acquiring new elements, it is already assuming a character which has nobility of expression, truthfulness of structure, and suitability to our special requirements. In time to come, further changes will doubtless be made; and thus the style which arose as an imitation of the past, will have become new, through constantly departing from the original type, and as constantly adopting new elements.

I have said that the decoration of a building should be brought about by the employment of such ornament as was, in time past, associated with the particular form of architecture employed in the building to be decorated, if a precisely similar form of architecture previously existed. Let not the ornament, however, be a mere servile imitation of what has gone before, but let the designer study the ornament of bygone ages till he understands and *feels* its spirit, and then let him strive to produce new forms and new combinations in the spirit of the ornament of the past.

This must also be carefully noted—that the ornament of a particular period does not consist merely of the forms employed in the architecture, drawn in colour on the wall, or the ceiling, as the case may be. The particular form of ornament used in association with some forms of Gothic architecture was very different in character from what we might expect from the nature of the architecture itself, and did not to any extent consist of flatly-treated crockets, gable ends, trefoils, cinquefoils, etc. The ornament of the past must be studied in its purity, and not from those wretched attempts at the production of Gothic decoration which we often see.

In what we may call the typical English house of the present day there is really no architecture, and if such a building is to be decorated it is as legitimate to employ one style of ornamentation as another. In such a case I should choose a style which has no very marked features—which is not strongly Greek, or strongly Gothic, or strongly Italian; and if there is the necessary ability I should say try and produce ornaments having novelty of character, and yet acknowledging (showing your knowledge of) the good qualities of all styles that are

past. If this is attempted, care must be exercised in order to avoid getting a mere combination of elements from various styles as one ornament. Nothing can be worse than to see a bit of Greek, a fragment of Egyptian, an Alhambraic scroll, a Gothic flower, and an Italian husk, associated together as one ornament; such an ornamental composition would be detestable. What I recommend is the production of new forms; but the new composition may have the vigour of the best Gothic ornament, the severity of Egyptian, the intricacy of the Persian, the gorgeousness of the Alhambra, and so on, only it must not imitate in detail the various styles of the past.

Now as to the decoration of a room. If one part only can be decorated, let that one part be the ceiling. Nothing appears to me more strange than that our ceilings, which can be properly seen, are usually white in middle-class houses, while the walls, which are always in part hidden, and even the floor, on which we tread, should have colour and pattern applied to them; and of this I am certain, that, considered from a decorative point of view, our ordinary treatment is wrong.

We glory in a clear blue sky overhead, and we speak of the sky as increasing in beauty as it becomes deeper and deeper in tint. Thus the depth of the tint of the Italian sky is familiar to us all. Why, then, make our ceilings white? I often ask this question, and am told that the whiteness renders the ceiling almost invisible; hence it is preferred. This idea is very absurd; first, because blue is the most ethereal and most distant of all colours (see Chap. V., page 191); and, second, do we not build a house with the view of procuring shelter? hence why do we seek to realise the feeling that we are without a covering over our heads? We only like a white ceiling because we have been accustomed to such from infancy, and because we have been taught to regard a clean white ceiling as all that is to be desired. I knew a Yorkshire lady who, upon being asked by her husband whether she would like the drawing-room ceiling decorated, replied that she thought not, as she could then have it re-whitewashed every year. The idea was clean certainly. Blue, I have said, is ethereal in character; it is so, and may become exceedingly so if of medium depth and of a grey

Fig. 39.—DESIGN FOR THE ORNAMENTATION OF A CEILING.

hue; hence, if a mere atmospheric effect was sought, it would be desirable that this colour be used on the ceiling rather than white. But, as we have just said, invisibility of the ceiling is absurd, as it is our protection from the weather. Further, the ceiling may become an object of great beauty, and it can be seen as a whole. Why then neglect the opportunity of arranging a beautiful object when there is no reason to the contrary? We like a beautiful coloured vase, or, if we do not, we can have it whitewashed, or even dispense with it altogether. We like beautiful walls, or we would have them whitewashed also; indeed, we like our surroundings generally to be beautiful. Why not, then, have beautiful ceilings, especially as they can be seen complete, while the wall is in part hidden by furniture and pictures?

I will suppose that we have an ordinary room to deal with. First, take away the wretched plaster ornament in the centre of the ceiling, for it is sure to be bad. There is not one such ornament out of a thousand that can be so treated as to make the ceiling look as well as it would do without it. Now place all over the ceiling a pattern which repeats equally in all directions (as Fig. 39), and let this pattern be in blue (of any depth) and white, or in blue (of any depth) and cream colour, and it is sure to look well (the blue being the ground, and the cream colour or white the ornament).

Simple patterns in cream colour on blue ground, but having a strong black outline, also look well; and these might be prepared in paper, and hung on the ceiling as common paper-hangings, if cheapness is essential. Gold ornaments on a deep blue ground, with black outline, also look rich and effective. These are all, however, simple treatments, for any amount of colour may be used on a ceiling, provided the colours are employed in very small masses, and are perfectly mingled, so that the effect produced is that of a rich coloured bloom (see Chap. VII., Vol. I., p. 229). A ceiling should be beautiful, and should also be manifest; but if it must be somewhat indistinct, in order that the caprices of the ignorant be humoured, let the pattern be in middle-tint or pale blue and white only.

I like to see the ceiling of a room covered all over with a suitable pattern, but I do not at all object to a large central ornament only, or to a centre ornament and corners; especially if the cornice is heavy, so as to give compensating weights in the margin. I have recently designed and seen "carried out" one or two centre ornaments for drawing-rooms, which ornaments were twenty-one feet in diameter. A centre ornament, if properly treated, may be very large without looking heavy; it may, indeed, extend at least two-thirds of the way from the centre to the margin of the ceiling.

If the ceiling is flat all ornament placed upon it must not only be flat also, but must not fictitiously represent relief, for no shaded ornament can be pleasant when placed as the decoration of an architectural surface.

TECHNICAL DRAWING.—XXX.

THE STEAM-ENGINE.

THE modern steam-engine owes its origin and development to the united genius and persevering industry of many inventors. Its influences upon the civilisation and comforts of the human race are incalculable, and it may be said with truth that no other mechanical contrivance has had so large a share in the unprecedented advancement that has taken place through the world during the present century. Even the printing-press, which ranks second, would never have accomplished so much without the untiring power of the steam-engine to drive it.

Like other great discoveries, its origin seems lost in obscurity. More than 2,000 years ago Hero of Alexandria described a reaction steam-engine, which is now used as a sort of toy; but the first to make a practical use of the elastic force of steam were the priests in the heathen temples, and the more scientific warriors of ancient story. They made hollow images of brass, idols or dragons, and filled them with water or spirits. Steam or vapour issuing from the mouth or nostrils seemed to indicate to the idol-worshippers the wrath of their gods, and the fiery dragons served to terrify an ignorant enemy.

The first man of whom any authentic record exists as having dimly dreamed of the latent power of steam, was Solomon de Caux, about the year 1614. His machine was a sort of fountain worked by steam; but the only result of his ingenuity was his own incarceration in the Bicêtre, the Paris lunatic asylum, by Cardinal Richelieu, the powerful minister of Louis XIV. Here he was visited by the Marquis of Worcester, who at length brought out his "Fire Water Work," a rude pumping-engine, and declared it to be an admirable and most forcible instrument of propulsion; but as the marquis was in disfavour, and suspected of being a madman, his machine attracted little public notice, and was never practically adopted. These experiments and others prepared the way for, and excited the notice of, future inventors, and Thomas Savery's improvements were quickly followed by Newcomen's engine, which contained the germ of the present Cornish pumping-engine. Its valves were moved by boys, and one of them, named Humphrey Potter, desiring to leave his irksome task for play, arranged cords attached to the engine so as to move the valves. This was a great improvement, and reflected much credit upon the youthful inventor. Brindley, Smeaton, and others made further progress; but the greatest improvements were made by James Watt, who is justly styled the father of the modern steam-engine.

In partnership with Matthew Boulton, of Soho, near Birmingham, Watt rapidly made numerous changes in Newcomen's engine, and brought the Cornish pumping-engine to the state in which it now exists. He also arranged the beam-engine to drive factories, and made many other minor improvements.

In 1802 Captain Trevithick patented the first locomotive, and several were used to drag colliery trucks in South Wales; but they were heavy and slow, and altogether inefficient for passenger traffic. After many alterations and improvements on the original idea, several different types of locomotive were invented, and in 1830 Stephenson's engine, the "Rocket," was worked most successfully on the Liverpool and Manchester Railway, and it contained the same general features as the locomotives now in use all over the civilised world.

Meanwhile engineers were not idle in their application of the same potent agency to the propulsion of ships. The first to realise and carry out this idea seems to have been a Spanish captain, Blasco de Garay, who in 1543 induced the Emperor Charles V. to allow him to put his idea into practice. No trustworthy accounts exist, but it is stated that his ship was moved by paddles, and had a steam-boiler on board. The ship seems to have moved at about four miles an hour in the harbour of Barcelona, but was not developed further.

In the beginning of the present century, Robert Fulton and others made several steam-ships, but the first which left England for America was the *Sirius* in 1838, followed quickly by the *Great Western*, and now there is hardly a sea or river where steam-ships are not seen.

Such, then, in brief outline, has been the history of this marvellous invention. Those only who have made the giant strides in its construction have their names and deeds known to fame, but hosts of inventors have emulated their exertions, and we see the results in the modern steam-engine.

Several distinct types of steam-engine are known, but unceasing change is still going on in matters of detail. It would be altogether foreign to the purpose of the present subject to enter into these matters, and two types only have been selected for illustration.

One, the vertical engine, as generally employed for marine purposes. The other, most universally known for stationary use, and the best for smaller sizes, namely, the horizontal high-pressure engine. This last forms the subject of the present lesson, and is preceded by detailed drawings of its various parts.

Before describing the details of this engine, it will be well to consider the subject of designing machinery. It should never be forgotten that art ought to have its full share as well as science, and if any parts seem disproportioned to an educated eye, it is a sure sign that they need correcting in some way. As with a building, so with a machine, each should have its own peculiar beauty; and there is as much art and good taste required for the design of an engine or machine as in planning a house or palace. But the forms suitable for a *stone* building are not proper for *iron* machinery: for example, the older side-lever marine engines were made strong and massive, but carved and ornamented like a Gothic building, with pointed arches, window-frames, mullions, capitals, etc.; while pedestals and shafts arranged upon this structure, with an utter disregard to position or fitness, gave to the whole thing a stupendous incon-

gruity. These strange mixtures of styles were, fortunately, as a rule, buried in the holds of ships; but they furnish most admirable lessons of what every designer of machinery should avoid. The true beauty of design in engineering design follows the same rules as those which render a group of statuary compass. The inconvenience of such an arrangement is very great; for the parts are with difficulty cleaned, cannot be seen or oiled, and therefore soon get out of repair. A very slight experience in machinery furnishes many illustrations of this defect, and it is peculiarly common with steam-engines. Cases

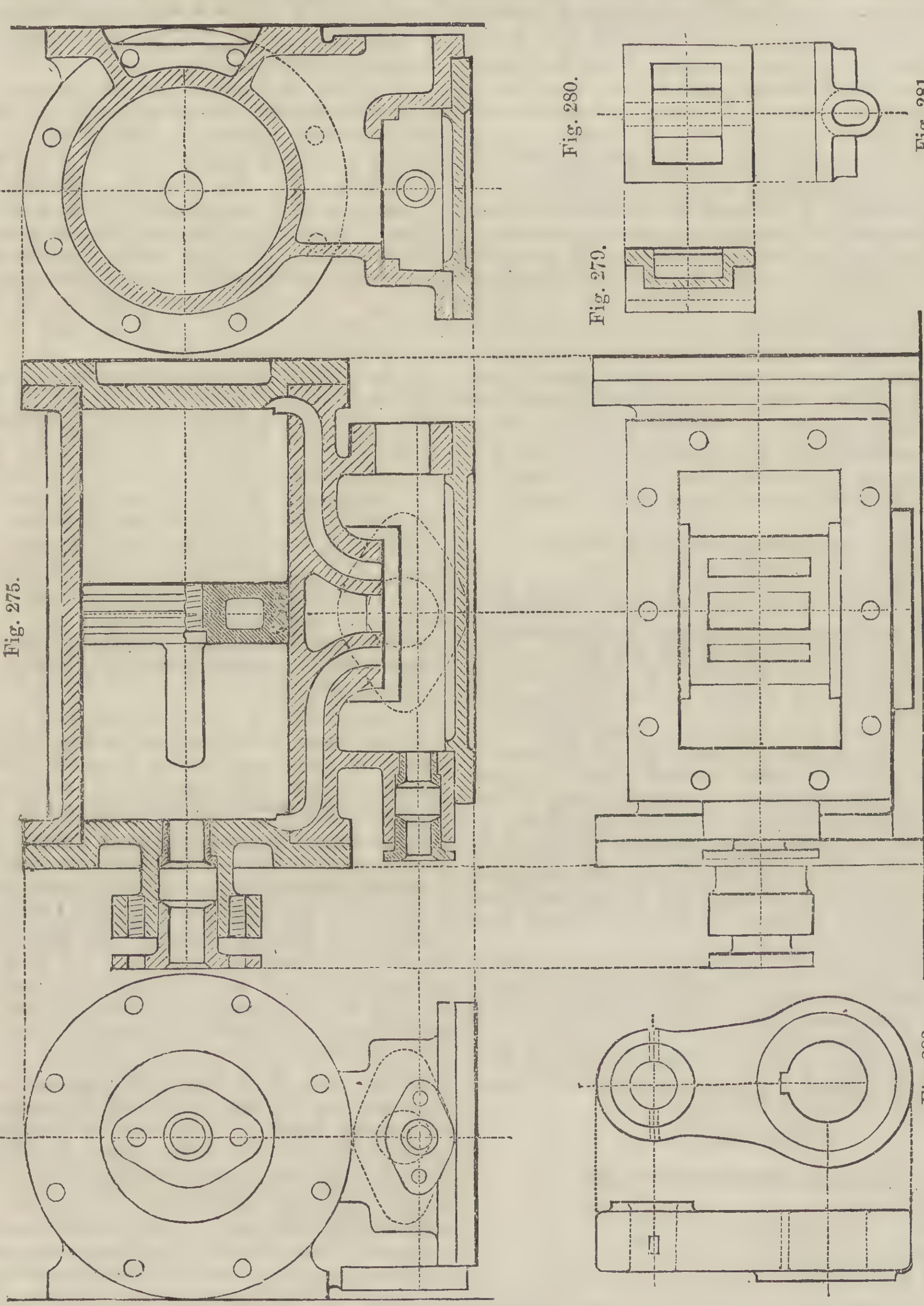


Fig. 277. Fig. 280. Fig. 281. Fig. 279. Fig. 275. Fig. 276. Fig. 278. Fig. 283. Fig. 282.

pleasing to the eye; and the graceful forms of a well-designed machine impress the mind with a sense of beauty, of fitness, and of power.

These remarks apply in favour of all the machines illustrated in this work, especially to those of Sir Joseph Whitworth, and to the drawings of steam-engines now under notice.

A great error is frequently committed by designers in attempting to pack their machines into the smallest possible compass.

exist, as on board ship, where economy of space is almost as important as economy of fuel, and there close packing is unavoidable, but in the majority of instances close packing of working parts is an evil to be avoided, and not an object to be sought. Another important consideration is the constructive detail, and it is here that experience becomes requisite, and any mere theoretical education fails altogether. All parts of an engine or machine ought to fit into their places without removing

those already fixed, and not, for example, require an entire framework to be removed in order to get in a shaft or wheel. The design should follow construction, and the machine be built up in imagination before being made in the workshop. Thus unsuitable arrangements may be detected, and the great expense of altering work already made avoided. Every part of a machine ought to possess equal strength, except in such cases as claymills, where accident or mischief may give a far heavier strain than the parts are calculated to endure. Where such circumstances exist, it is desirable to have a cheap simple casting made, weaker than the rest of the mill, so that fracture shall take place in it rather than in the more costly parts.

The knowledge of proper proportions cannot be perfectly acquired otherwise than by observation and experience, and it is excellent practice to copy good machinery drawings, or the machines themselves. The strength of materials forms a useful basis for this knowledge, but so great a margin is necessary to allow for irregular strains and ensure rigidity of the parts, that calculations of theoretical strength in machines, although interesting and useful, are, as a rule, exceedingly difficult in their application, and practical experience is found absolutely necessary.

Cost of construction is affected much more by design than workmanship, and a machine well designed and constructed is invariably cheaper than one badly designed and made. Mere cheapness is a thing to be avoided, and simplicity should take its place. It is the duty of the designer to arrange the parts or details so that they may be easily and cheaply made, while effectually answering their intended purposes: the amount of labour he may save is much more than can ever be gained by careless workmanship, to say nothing of the more satisfactory results.

GENERAL DESCRIPTION OF ENGINE DETAILS.

Scale, one inch and a half to the foot.

Fig. 275 is a horizontal section of the cylinder and valve-box, showing the steam-ports, passages, and many other details. Fig. 276 is a side elevation, with the front view of steam-ports, the valve-box cover being removed; and Fig. 277 is a cross-section through the middle of cylinder, at right angles to its axis. Fig. 278 is a front elevation to show the cover, bolt-holes, and glands. Inside the cylinder is a piston, shown in section and elevation, known as Ramsbotham's Patent. The packing consists of several thin steel rings, held in grooves in the cast-iron block, while steam, admitted behind them, allows their own elasticity to keep the rings against the smooth inner surface of the cylinder, and so retain a steam-tight joint.

The inlet and outlet ports for steam are clearly shown by Figs. 275 and 277, the latter being made of larger dimensions, so as to carry away the greater volume of expended steam after it has driven the piston. The object of having the exhaust-pipe taken from below is to carry off all the condensed water from the cylinder.

Figs. 279, 280, and 281 are three views of the slide-valve, called a short D-valve, from its appearance being originally like that letter. This valve covers over the ports, and being moved by an eccentric (shown in the next lesson), it admits and exhausts steam at proper intervals.

The crank (Figs. 282 and 283) is shown in side and front view; it fits upon the end of the main shaft, and is the means of converting rectilinear into rotary movements.

APPLIED MECHANICS.—XI.

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THE TURNING-LATHE AND THE SLIDE-REST.

THE turning-lathe is the most important tool used in giving definite form to masses of iron or other substances. It enables us to produce with perfect accuracy any surface of revolution. The nature of a surface of revolution will be understood from Fig. 1 in the opposite page. A curve, A Q P B, is conceived to revolve about the line A B. It describes a surface, the nature of which depends upon the form of the curve A Q P B. If this were a semicircle, as in Fig. 2, the surface traced out is that of a sphere. If A Q P B formed a rectangle, as in Fig. 3, then the line P Q produces a cylinder, while A Q and B P form the circles which are at the ends of the cylinder. If A Q B form a triangle, as in Fig. 4, the line B Q traces out a cone, and A Q forms the circle at the base of the cone. The axis A B, about which the curve revolves, may be entirely independent of the arm, as, for example, in Fig. 5, in which the circle P Q revolves around the line A B. In this case the circle traces out a ring. It will be seen from these simple examples that a great multitude of different forms are surfaces of revolution. In fact, the majority of symmetrical forms are of this class.

All surfaces of revolution have one property in common which arises from the nature of their mode of generation. We shall fix our attention upon the point P (Fig. 1). Let fall a perpendicular, P R, from P upon the axis of revolution, A B. The line P R remains of constant length when the curve rotates about the axis A B. The point P must therefore describe the circumference of a circle of which R is the centre and P R the radius. The same is obviously true for every other point along the curve A Q P B. It follows, therefore, that the entire surface of revolution is produced by each point in the curve describing a circle. We may state the same property in slightly different language. Suppose a plane perpendicular to the axis A B to be drawn, then the intersection of this plane with the surface of revolution is always a circle.

To form, therefore, a surface of revolution from a piece of material, it is only necessary to produce a series of circles the centres of which lie upon the axis of revolution. If these circles have equal radii, then the surface of revolution is a cylinder (Fig. 3). If the radii increase uniformly from one end of the axis to the other, then the surface is a cone (Fig. 4).

The turning-lathe is a tool by which circles can be produced, and since the radii of the circles can be disposed at pleasure, the turning-lathe provides the means of producing surfaces of revolution. If we remember how important are the forms of the cylinder, the cone, and the sphere, not to mention the other surfaces of revolution, we shall be able to understand the vast utility of the lathe in the arts of construction.

The simplest form of the turning-lathe is shown in Fig. 6. This lathe is intended to be worked by the foot, but in principle is the same as if intended to be worked by a steam-engine or other source of power.

The action of the crank will be understood by Fig. 7. C E is the foot-board; this turns around a centre at C, and at the point F the pressure of the foot is applied. Thus the foot-board is a lever of the third order, of which C is the fulcrum, E the point of application of the resistance, and F the point of application of the power. It follows from the principle of the lever, which we have already explained, that the power at F is to the load at E in the ratio of the two lines C E and C F. If F be applied midway between C and E, as is usual in the treadle of a lathe, the power at E will be half the power at F. There is, therefore, a diminution of power for the purpose of increased convenience in the mode of working. The power is transmitted from the foot-board, C E, to the crank, O D, by means of the connecting-rod, E D. As the foot-board oscillates to and fro, the crank performs complete revolutions. It is obvious that in a foot-lathe the power can only be applied during the descent of the foot-board; the power is therefore only transmitted to the axle at O during a portion of the revolution. In order to enable the work of the lathe to be performed continuously, some means must be devised by which the energy imparted to the machine during the descent of the foot-board shall be equalised throughout the entire rotation. For this purpose a heavy fly-wheel, shown at F (Fig. 6), is attached to the axle. As we have already explained, when treating of the punching-machine, energy can be stored up in the fly-wheel. By this means the impulsive action of the foot is moderated, and the energy which is stored up when the action is too great is sufficient to carry on the work of the lathe during that portion of the revolution when the power has ceased to act. In the figure two cranks and connecting-rods are shown; this is usual in long lathes, because it is desirable that the foot should always be near the connecting-rod.

The fly-wheel is called upon to perform another duty besides that of equalising the motion on the circumference of the wheel. At F three grooves will be seen; upon the centre groove is a band, which passes up to the bed of the lathe, and embraces a corresponding groove in the pulley shown at G. The object of this band is to transmit the motion from the axle A B to the

work upon which the lathe is engaged. The action of the band will be understood from Fig. 8. In this figure A and C are two wheels which are embraced by the same band. Let us suppose that the wheel A is revolving in the direction shown by the arrows. If the band be properly tightened it will be impossible for the wheel to revolve without drawing the band towards it upon the one side and allowing it to pass away upon the other, as shown by the direction of the arrows. The motion of the band arises from the friction between the band and the wheel; this friction is so large that it is impossible for the band to slip unless the resistance opposed by the work be too large. Precisely as the wheel A makes the band to move, so the wheel C is moved by the band. It will be evident from an inspection of the arrow-heads that the wheel C is made to revolve in the same direction as the wheel A. Had A and C been toothed wheels, geared one into the other so that the revolution of A caused the revolution of C, C would have rotated in the opposite direction to the rotation of A.

It is easy to see that the velocities with which the wheels revolve are in the inverse proportion of their diameters. When the wheel A has performed one revolution, it will have delivered

know the dimensions of the pulleys and the distance between their centres.

Let the radius, A B, of the larger pulley be R, and C D be R′, and let d be the distance, A C, between the centres.

Let fall from C the perpendicular, C P, upon the radius, A B. The length of the band is composed of four portions, namely, the two portions of the common tangents intercepted between the circles, and the two portions of the circles which are embraced by the band. The lengths of these portions have to be found separately, and their sum will then give the required length of the band.

The common tangent, D B, is equal to C P; but since A C P is a right-angled triangle—

$$AP^2 + CP^2 = AC^2.$$

But $AP = AB - BP = AB - CD$, since P B D C is a parallelogram;

$$\therefore\ AP^2 = (AB - CD)^2 = (R - R')^2.$$

Hence we have—

$$(R - R')^2 + CP^2 = AC^2 = d^2;$$

$$\therefore\ CP^2 = d^2 - (R - R')^2;$$

$$\therefore\ CP = \sqrt{d^2 - (R - R')^2}.$$

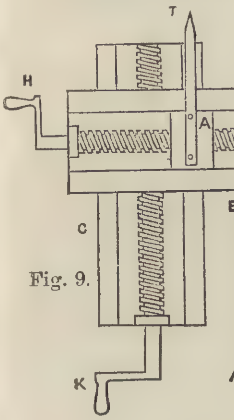


Fig. 9.

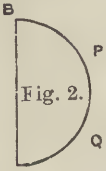


Fig. 2.

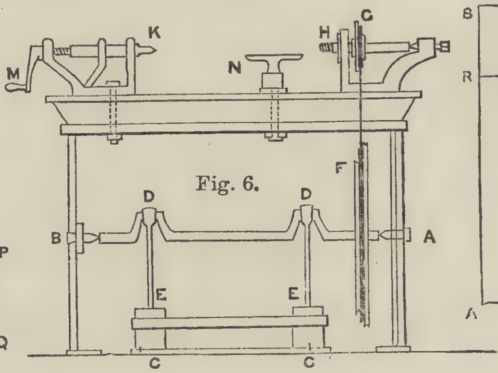


Fig. 6.

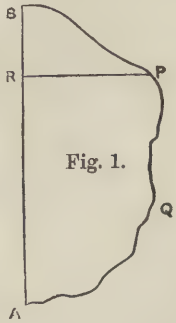


Fig. 1.

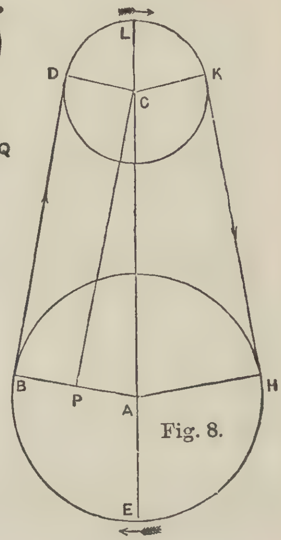


Fig. 8.

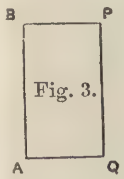


Fig. 3.

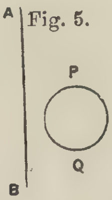


Fig. 5.

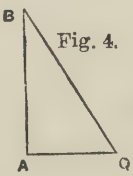


Fig. 4.

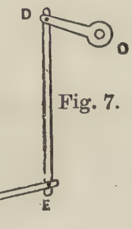


Fig. 7.

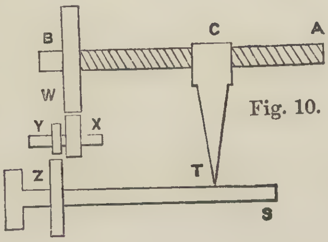


Fig. 10.

a length of the band equal to its circumference to the wheel C. Therefore C will have to perform as many revolutions as the length of its circumference is contained in the circumference of A. Therefore the velocities must be inversely proportional to the circumferences—that is, inversely proportional to the diameters. If, for example, the large wheel A were ten times as great as C, and if A revolved once in a second, C will revolve ten times in a second.

The wheel F, in Fig. 6, thus serves not only as a fly-wheel, but also for the purpose of increasing the velocity of revolution, as it would be impossible by the action of the foot to give the work a velocity so great as is required for some kinds of work. It will be noticed that there are three grooves on the wheel F, and three corresponding grooves in the wheel G. The magnitudes of these grooves are so proportioned that the same band will apply to each pair. Thus, when the greatest speed is required for the work, the band is placed upon the largest groove on F and the smallest groove on G; when a medium speed is required, the band is placed upon the centre groove in each wheel; and when the lowest speed is required, the band is placed upon the smallest groove of F and the largest groove of G.

As bands occur so often in machinery, and as we shall have occasion to refer to them subsequently in these lessons, it will be well to investigate the general formula for determining the proper length of the band which shall be employed when we

Hence the length of the common tangent is expressed in terms of the radii and of the distance between the centres.

To find the length of the part embracing the circle, it will be necessary to compute the angle B A C.

$$\text{Cos. } BAC = \frac{AP}{AC} = \frac{R - R'}{d}.$$

Hence, by reference to a trigonometrical table, the value of the angle B A C can be found expressed in degrees.

Since the arc of a circle is proportional to the angle it subtends at the centre, the length, B E H, must be to the whole circumference in the proportion which the angle subtended by B E H bears to four right angles. The angle subtended by B E H is equal to four right angles, minus the angle B A H, and it is evident that the line A C bisects the angle B A H, and that, therefore, the angle B A H is equal to double the angle B A C, which we have already determined. We have, therefore, the following proportion:—

$$\text{arc } BEH : \text{circumference} :: 360° - 2 \times BAC : 360°;$$

but the whole circumference is $\frac{44}{7}R$.

$$\therefore\ \text{arc } BEH = \frac{360° - 2N°}{360°} \times \frac{44R}{7}.$$

We can also find the length of the arc, D L K, upon the smaller circle.

The angle D C L is equal to the angle B A C, since the line C D is parallel to A B, and therefore the arc D L K is found by the following proportion:—

$$\text{Arc } DLK : \frac{44}{7}R' : : 2N^\circ : 360^\circ;$$

$$\therefore \text{ arc } DLK = \frac{2N^\circ}{360^\circ} \times \frac{44R'}{7}.$$

Adding, therefore, these two lengths to double the length of the common tangent, the total length of the band becomes known.

It is also easy from the same principles to ascertain the proper magnitude of the grooves in the wheels, in order that the same band shall be applicable to every pair.

By means of the band the pulley G, on what is called the "mandril" of the lathe, is made to turn rapidly: attached to the mandril is a screw, H. This screw does not itself generally support the work: it bears what is called a "chuck," in which the work is held. The chucks used are of very varied forms, depending upon the character of the work upon which the lathe is engaged. It may be said, in general, that a chuck is a means of conveniently attaching the work to the mandril, so as to make the work partake of the rotation of the mandril. At the opposite end of the bed of the lathe is a point, K: this point is capable of being brought forward by a screw turned by a handle, M: this point should lie exactly in the prolongation of the axis of the mandril. The work is thus held securely between the point and the chuck. For short pieces of work, however, the point is often found not to be necessary; but when the work has considerable length, it would be impossible without the point to secure it so firmly in the chuck that the application of the cutting-tool should not cause it to swerve a little from the proper position.

In ordinary tools, such as the saw, chisel, or plane, the work remains at rest while the tool is moved. In the lathe, however, it is the work which is moved, while the tool remains at rest. This is the case in the more usual applications of the lathe, but occasionally, particularly in ornamental turning, a movable tool is employed. This we shall not delay to consider, as we wish to treat principally of the practical applications of the lathe, rather than of the more fancy uses to which it is occasionally put.

In the lathe shown in Fig. 6, the tool is held in the hands of the workman; the rest N is placed near the work; and while the edge of the tool is in action, the shank is held firmly upon the rest. Since the work revolves rapidly about an axis, it follows that when the point of the tool is applied it must trace out an exact circle upon the work; and since the radius of this circle can be of any magnitude, within reasonable limits, and also since the tool can be moved along the work, it follows that any figure of revolution, as already defined, can be produced by the lathe.

One of the most important uses to which the lathe is applied is the production of a perfect cylinder. The piston-rod of a large steam-engine, for example, should be as nearly as possible perfectly cylindrical. The inside of the steam cylinder should also be perfectly uniform if leakage is to be avoided. Now, to produce a cylinder with the lathe we have shown in Fig. 6, or with a power-lathe adapted to the magnitude of the work, upon the same principle, is a work of no little difficulty, and demanding great skill on the part of the workman. It is extremely difficult, nay impossible, for the most skilled mechanic to hold and move his tool with such precision that the figure he produces shall not have a section slightly larger or smaller in some places than others, and thus making his work deviate from the truly cylindrical form. To meet this difficulty the slide-rest was devised, which, holding the tool with perfect steadiness, and moving it with perfect regularity, enables the lathe to turn out a profusion of perfect forms, with the minimum amount of skilled attendance.

The slide-rest is really an iron hand which holds the tool and enables it to be turned towards the work, or from it, or moved parallel to the bed of the lathe, with facility and precision.

The character of the slide-rest will be understood from Fig. 9, which represents the essential features in a diagrammatic manner. T is the tool. This tool is firmly attached to a small stage, A, by means of screws. The stage, A, is mounted upon a slide, B, and by means of the handle shown at H, and the screw which is attached to it, and which works in a nut underneath A, the stage A can be moved to the right or left. Just as the stage A is mounted upon the slide B, so the slide B is itself mounted upon the slide C, the screws at C and B being at right angles to each other. It follows, therefore, that, by properly turning the handles H and K, the point of the tool can be placed in any required position in the plane, to which its movement is restricted.

The slide C is itself fastened to the bed of the lathe by a clamp, so that it can be secured in any position that may be required. If the screw B be placed parallel to the axis of the mandril, then, by turning the handle H, the point of the tool will be moved in a line parallel to the axis of the lathe, and will, therefore, turn a perfect cylinder. By turning the handle K at the end of each cut, the point of the tool may be advanced so as to be ready to take a fresh cut.

When the slide-rest had been invented, it was a natural step to make the lathe self-acting, so that the tool should be moved uniformly by the machine itself without the aid of the workman. This object is obtained by having a screw along the bed of the lathe; the slide C, instead of being clamped to the bed, is attached to a nut upon this screw, so that when the screw along the bed of the lathe is made to revolve, the slide-rest is carried with a perfectly uniform motion.

We shall conclude this account of the lathe and slide-rest by a short description of the principle of screw-cutting, which is one of the many important applications of the lathe.

The principle of the screw-cutting lathe is shown in Fig. 10. A leading screw, A B, which should be made with extreme care, runs along the bed of the lathe, and passes through a nut, C, on the slide-rest: the machine receives motion by the pulley D, which carries the band from the fly-wheel or from a neighbouring shaft, if the lathe be worked by steam power. D is on the mandril of the lathe, to which the work S, on which the screw is to be turned, is attached. The motion is conveyed from the pulley D to the screw A B, by the intervention of the train of wheels, Z, Y, X, W. These wheels are toothed, and upon them depends the pitch of the screw which is made. Let us suppose that the leading screw, A B, contains n threads to the inch, and that the numbers of teeth in the train of wheels are denoted by the numbers Z, Y, X, W; we shall be able to find the number of threads produced on the work.

When A B has made n revolutions, the tool T will have been moved one inch, therefore the number of revolutions that the work has made will be the number of threads the screw traced upon it contains in the inch. When the wheel W, which is fixed upon A B, has revolved n times, the wheel X has revolved

$$\frac{W}{X}n \text{ times.}$$

The wheel Y is on the same shaft as X, and turns with it, therefore Y makes one revolution for each revolution of X, and Z will make

$$\frac{Y}{Z}$$

revolutions for every revolution of Y. Hence it follows that for every n revolutions of A B the work S will revolve

$$n \cdot \frac{W \cdot Y}{X \cdot Z}$$

times, and that, therefore, this will represent the number of teeth to the inch on the screw which is produced.

Suppose, for example, the leading screw had two threads to an inch, and that we have a series of wheels containing 10, 15, 20, etc., up to 100 teeth, and then by tens up to 200, it is easy to select four which shall cut a thread of any required pitch. If a screw of eight threads be required, we have

$$8 = 2\frac{WY}{XZ},$$

$$\text{or } 4 = \frac{WY}{XZ};$$

$$\text{therefore } W = 100,\ X = 50,\ Y = 100, \text{ and } Z = 50$$

will give one set of wheels, but numerous others would have answered equally well.

Suppose a screw of fifteen threads to the inch be required,

$$15 = 2\frac{WY}{XZ}.$$

$$W = 100,\ X = 20,\ Y = 60,\ Z = 40.$$

A small expenditure of ingenuity will enable trains to be selected which shall produce screws containing no entire number per inch. For example, to produce a screw four inches of which shall contain forty-five teeth, we have—

$$\frac{45}{4} = 2 \cdot \frac{WY}{XZ},$$

$$\text{or } \frac{WY}{XZ} = \frac{5 \times 9}{4 \times 2} \times \frac{50 \times 90}{40 \times 20};$$

$\therefore$ W = 50, Y = 90, X = 40, Z = 20 will give the required result.

Had the leading screw contained any other number of threads to the inch the calculations would be equally easy.

VEGETABLE COMMERCIAL PRODUCTS.
XVIII.
TANNING MATERIALS (*continued*).

NUT-GALLS (*Quercus infectoria*).—This tree abounds in Asia Minor. The galls are excrescences upon the young twigs, produced by the punctures of an insect, a species of *Cynips*. The market is chiefly supplied from the ports of the Levant, whence they are called Aleppo galls. They contain much tannin and gallic acid, and are largely employed both in tanning and dyeing. We receive nut-galls from Turkey, Greece, the Ionian Islands, Hungary, and Sclavonia, *viâ* Vienna, Trieste, Leghorn, Genoa, and Marseilles. One kind, called the *knoppern*, is distinguished from the smooth gall-nuts by many angular and rough excrescences, as well as by having the essential principles in greater strength.

DIVI-DIVI (*Cæsalpinia coriaria*; natural order, *Leguminosæ*).—This tree is a native of the salt marshes of Curaçoa, Carthagena, and other places in South America. It furnishes in abundance a brown pod, about the size of that of the pea, but curved into the form of the letter S. This pod is very astringent, and therefore of great value in tanning. The Indian name, *divi-divi*, has been adopted by our merchants. It is not used alone, but is generally mixed with oak-bark and valonia. In 1851 more than 3,000 tons were imported.

CATECHU (*Acacia catechu*; natural order, *Leguminosæ*).—A thorny tree; a native of Hindostan. Catechu is procured by cutting the wood into chips, boiling them, and then straining the liquor, and evaporating it until it assumes the appearance and consistency of tar. This substance hardens as it cools, is formed into small squares, dried in the sun, and is then fit for market. Catechu contains a large proportion of tannin. Packed in mats, it is sent to this country in large quantities from India. Several varieties of it are known to merchants by the names of catechu, terra japonica, cutch, and gambier. Dissolved in water, it tans skins very rapidly—one pound of catechu being equivalent to seven or eight of oak bark; but the leather is not so durable or good as that which is more slowly prepared from oak-bark.

BETEL-NUT PALM (*Areca catechu*, L.) grows in most parts of the East Indies. The trunk is straight and slender, and from forty to fifty feet in height; the fruit is about the size and shape of a small egg, and the nut itself rather larger than a nutmeg, roundish-conical, and brown in colour.

The betel-nut furnishes an astringent extract, which constitutes one or more varieties of the catechu of commerce. But the principal consumption of the betel-nut is for chewing, in combination with the pepper leaf of the *Chavica betel* and lime. For this purpose the nuts are divided into quarters, one of which, rolled in the pepper leaf and sprinkled with lime, forms the quantity generally used. This mixture gives a red tinge to the saliva, and seems to have some narcotic power. It is in general use as a masticatory amongst the natives of the East Indies, much the same as tobacco in other countries.

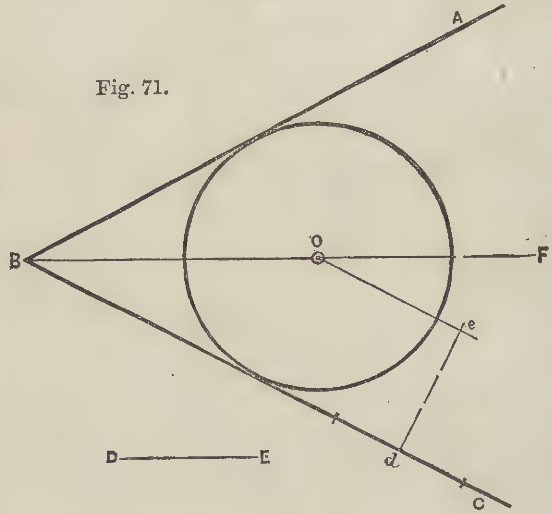
On persons who are unaccustomed to chewing this preparation it has a very unpleasant effect, for the drug causes giddiness and staggering, takes all the skin off the mouth and lips, and destroys for some time all sense of taste. But when all this has been overcome—and it requires no little perseverance to accomplish it—the taste is said to be agreeable, while its use is beneficial. Thus it is stated by Sir James Emerson Tennent, the author of a valuable work on Ceylon and the habits and customs of the Cingalese, that it furnishes these people, who are not meat-eaters, with an antacid, tonic, and carminative which are absolutely necessary to them to correct the effects of a purely vegetable diet.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—VIII.

THE following figures are given to assist students in drawing pitch circles of wheels working in gear with each other, and will be found most important in numerous constructions where curves are to touch each other or to merge out of straight lines. These, too, it will be found, have been and will be further worked out in the lessons in Technical Drawing.

To draw a circle of a given radius, D E, *which shall touch both sides of an angle,* A B C (Fig. 71).

Fig. 71.



Bisect the angle by the line B F.

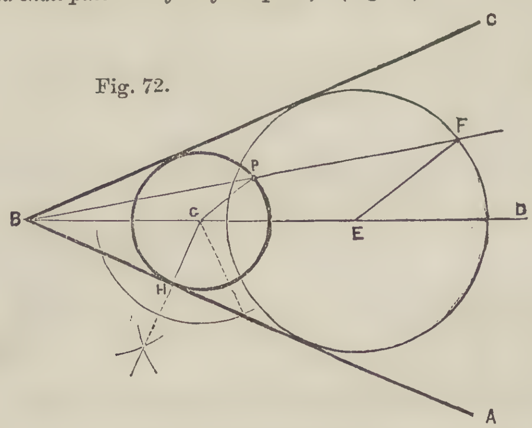
On either of the lines of the angle erect a perpendicular equal to the given radius D E—viz., *d e*.

From *e* draw a line parallel to B C, cutting the bisecting line in O.

From O, with the given radius, draw the circle, which will touch both the lines of the angle.

To draw a circle which shall touch both lines of an angle, and shall pass through a given point, P (Fig. 72).

Fig. 72.



Let A B C be the given angle, and P the given point, through which the required circle is to pass.

Bisect the angle A B C by the line B D.

From any point in B D, as E, draw a circle, touching both lines forming the angle.

From B draw a line through P, cutting this circle in F.

Join F to E, the centre of the circle.

From P draw a line parallel to F E, cutting the bisecting line B D in the point G.

From G draw a line perpendicular to A B (by Fig. 6, Vol. I., page 64)—viz., G H.

Then, with radius G H, which will be found to be equal to

G P, describe a circle which will touch both lines forming the angle.

To draw a series of circles to touch each other and two lines not parallel (Fig. 73).

Produce A B and C D until they meet in E.

Bisect the angle A E C by E D′.

Draw the first circle at pleasure, and from its centre, X, draw a radius, X F, at right angles to E A.

From G draw G H perpendicular to E D′. From H, with radius H G, describe an arc cutting E A in I. Draw a line at I, perpendicular to A E, cutting E D′ in J.

From J, with radius J I, describe the next circle, cutting E D′ in K.

From K draw a line perpendicular to E D′, cutting E A in L.

From L, with radius L K, describe an arc cutting E A in M.

From M draw a line perpendicular to E A, cutting E D′ in N.

From N, with radius N M, describe a circle touching K, and cutting E D′ in O.

From O draw O P perpendicular to E D′.

From P, with radius P O, describe an arc cutting E A in Q.

From Q draw a line perpendicular to E A, cutting E D′ in R.

From R, with radius R Q, describe the next circle.

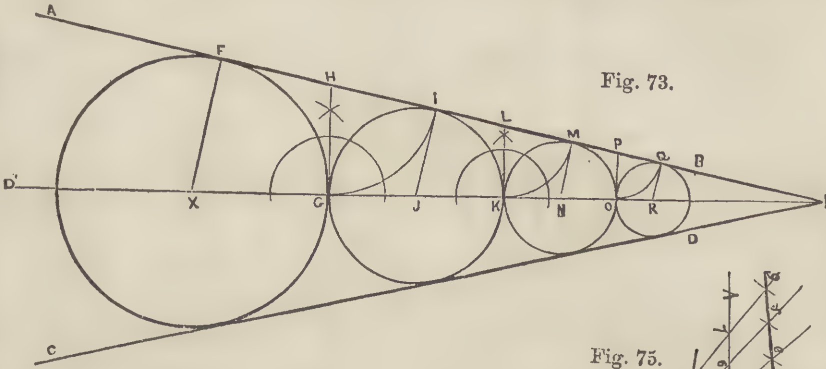


Fig. 73.

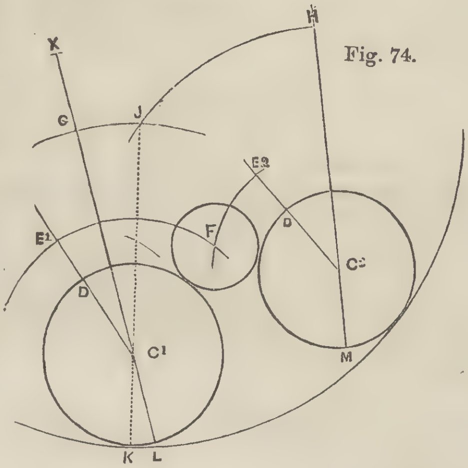


Fig. 74.

Any number of circles may be thus described.

To draw a circle of a given radius, to touch two given circles, C^1 and C^2 (Fig. 74).

Draw any radius in each circle, C^1 D and C^2 D, and produce them.

On these radii, beyond the circles, add to each the radius of the required circle—viz., D E^1 and D E^2.

From C^1 with radius C^1E^1, and from C^2 with radius C^2E^2, describe arcs cutting each other in F.

From F, with radius E′D, describe the required circle, which will touch both circles.

If the required circle is to include both circles, draw any radius in each, as C^1 L, C^2 M.

Produce both these radii.

On the radius C^1, set off from L the radius of the required circle—viz., to X. Diminish this by the radius of circle 2—viz., to G.

On radius M C^2 set off L G—viz., M H.

From centres C^1 and C^2, with radius C^1 G and C^2 H, describe arcs cutting each other in J.

From J draw a line through C^1 to K.

With radius J K, describe the enclosing circle, which will touch circles C^1 and C^2.

THE CONCHOID* (Fig. 75).

The conchoid is a curve which always approaches a straight line, but never reaches it, however far the curve and straight line may be produced.

The straight line A B is called the *asymptote*, C D the diameter, and P the pole.

The asymptote A B, pole P, and diameter C being given, draw C P at right angles to A B.

On each side of D set off any number of equal parts, 1, 2, 3, 4, 5, 6, 7.

From P draw lines passing through these points.

From 1, 2, 3, etc., with radius D C, describe arcs cutting these lines in *a*, *b*, *c*, *d*, etc., and through these intersections trace the curve. The curve above the asymptote is called the *superior* conchoid. By setting off the same lengths *under* the line the *inferior* conchoid is obtained.

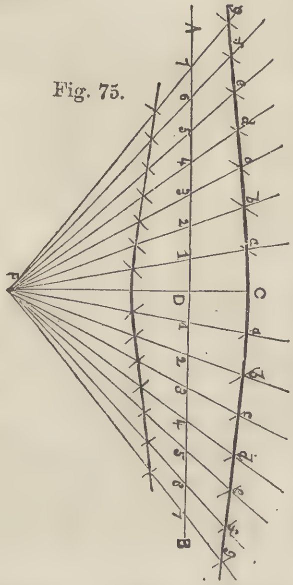


Fig. 75.

The conchoid has been used in architecture in drawing the slightly curved line which forms the profile or side of columns, called the *entasis*.

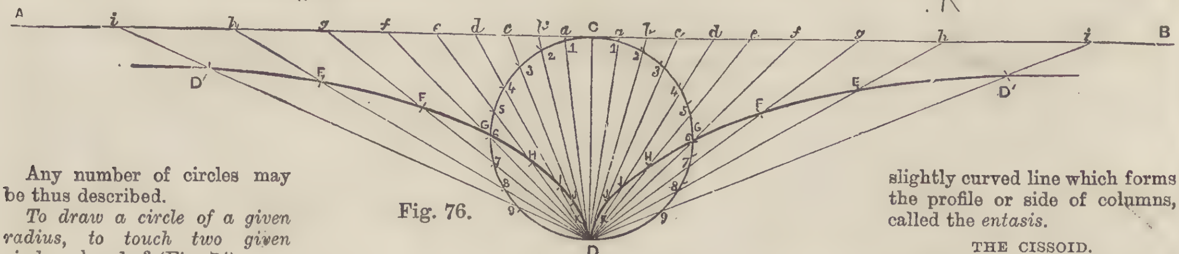


Fig. 76.

THE CISSOID.

This figure is sometimes called the cissoid of Diocles, from the name of its discoverer, who flourished about A.D. 150.

To draw the cissoid (Fig. 76).

Draw any line, A B, and C D perpendicular to it. On C D describe a circle. From the extremity D of the diameter, draw any number of lines at any distance apart, passing through the circle, and meeting the line A B in *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, and *i*.

Take the length from *i* to 9, and set it off on the same line on each side from D—viz., to D′, D′.

Set off the length *h* 8 from D—viz., points E, E.

Set off the length *g* 7 from D—viz., points F, F.

Proceed thus with all the lines, and trace the double curve through D′ D′, E E, F F, G G, H H, I I, J J, K K, etc.

* The conchoid was invented by Nicomedes about A.D. 450.

VEGETABLE COMMERCIAL PRODUCTS.

XIX.

VIII. PLANTS REMARKABLE FOR THEIR NARCOTIC AND POISONOUS PROPERTIES, YET USEFUL AS REMEDIAL AGENTS.

OPIUM (*Papaver somniferum*, L.; natural order, *Papaveraceæ*).—The poppy is an annual plant growing from two to four feet high, having flowers with two sepals and four white petals, with a violet spot at the base of each petal. Stamens numerous; pistil, a globular ovary or capsule, surmounted by a radiated stigma, containing partial dissepiments and numerous seeds.

The opium poppy is a native of Persia, and probably also of the south of Europe and Asia Minor. It is largely cultivated in those countries, and also in Egypt, Arabia, and British India, for the sake of its opium. Dr. Joseph Hooker thus describes this process:—"The capsules are sliced in February and March with a little instrument like a saw, made of three serrated plates tied together. From the incisions made by this instrument the opium oozes out as a milky juice, which as it dries becomes a soft brown sticky paste; each morning this paste is scraped off by means of small shells, and collected into jars, the contents of which are afterwards made into balls of about half a pound weight; these are often coated with the seeds of some species of *Rheum* or rhubarb plant. The balls are packed into chests, and exported to other countries."

Opium is produced in large quantities in India for consumption in China, on account of the great sale there, in spite of all prohibitions. Eastern nations generally are very fond of opium, which they smoke with their tobacco, or alone, and take in the form of pills. With us, it is much used in medicine as an anodyne, especially in the well-known preparation called laudanum.

In 1852 fifty-one tons of opium were imported into the United Kingdom, principally from the East Indies and Turkey. Turkey opium is considered to be the best, especially that which comes from Smyrna.

THE OPIUM POPPY (PAPAVER SOMNIFERUM).

TOBACCO (*Nicotiana Tabacum*, L.; natural order, *Solanaceæ*).—The tobacco plant is an annual, growing six feet high, having alternate, oblong, lanceolate, sessile leaves, and dingy red, funnel-shaped flowers. The leaves are viscid and pubescent, and are the parts used in the manufacture of the tobacco.

The tobacco plant is indigenous to the warm parts of America, and was unknown in the Old World before the discovery of that continent. It was first brought to the notice of the Spaniards in the year 1492, when Columbus and his companions saw the natives of Cuba smoking cigars. It was introduced into England in 1586 by Sir Francis Drake, from Virginia, where an English colony had remained for a year. The colonists are said to have brought tobacco with them on their return, and to have introduced into this country the practice of tobacco-smoking, or, as it was at first called, tobacco-*drinking* or *sucking*. Sir Walter Raleigh and other young men of fashion gave it every encouragement, by smoking themselves, and the habit was soon acquired by the English, as it had previously been by the Spaniards, the first method of imbibing the fumes being by means of a walnut-shell and a straw. The tobacco plant appears to thrive in all parts of the world in warm climates, and is now cultivated almost everywhere. The practice of smoking has become almost universal, both amongst savage and civilised nations; for no habit is more easily acquired or more difficult to relinquish than the use of this weed; hence its rapid progress amongst nations, in spite of all the efforts of their rulers at prohibition. The priests and sultans of Turkey and Persia declared smoking to be a sin against their holy religion; yet the Turks and Persians became the greatest smokers in the world. Pope Urban VIII. fulminated a bull against the use of tobacco, but the anathema fell to the ground. In Russia the smoker was threatened with the knout for the first offence, and with death for the second; yet the Russians are now constantly with pipes in their mouths. In our own country James I. wrote a book against it, called "A Counterblaste to Tobacco;" but instead of checking, it rather tended to promote the spread of the habit among his subjects.

Tobacco is manufactured in various forms to fit it for smoking, chewing, or snuffing, and the annual consumption in these different forms is so enormous that no estimate can be made of the quantity. In 1868 the imports into the United Kingdom amounted to 49,016,582 pounds of unmanufactured tobacco, and 3,051,398 pounds of manufactured tobacco, cigars, and snuffs; and some other nations are more addicted to the use of tobacco than ourselves.

After the plants have done blooming they are cut down and hung up to dry on poles; the leaves are then stripped from the stems, sorted, packed in boxes or casks, and shipped. On arriving in this country the leaves are taken out of the casks, and when their midribs have been removed, are spread on the floor and moistened with water. This is all that English manufacturers are allowed to do; on the Continent salt and sugar are added. The leaves are then compressed into dense cakes and cut with a machine; and the cut tobacco, shaken out and afterwards steamed, is called, according to the leaf used, *Virginia shag*, *Maryland returns*, etc. In *Bird's-eye* tobacco the midrib is allowed to remain in the leaf, and forms those little white bits which have given it its fanciful name. The dried leaves, moistened with sugar and water, and pressed into cakes, form *Cavendish* and *Negrohead*, used for chewing and smoking. The same leaves moistened with sugar and water, beaten until soft, and then twisted into a sort of string, constitute *Pig-tail*. The leaves and stalks ground to powder and roasted form snuff, which is variously scented to suit the different olfactory tastes of customers. Cigars are only the dried leaves deprived of their midribs and wound into a sort of

spindle form; cheroots are a variety of cigar, cut straight at each end, cylindrical, and tapering, broader at one end than the other; cigarettes are made by rolling up a small quantity of cut tobacco in a piece of paper (the leafy covering of the Indian corn is preferred), they are then smoked the same as cigars, but usually by moderate smokers.

There are numerous varieties of tobacco found in commerce. The principal sorts are—

North American tobacco, chiefly from the states of Virginia, Maryland, and Kentucky; but now, Tennessee, North Carolina, Louisiana, and Missouri also produce tobacco. Usually imported in hogsheads in the leaf, hence called leaf-tobacco.

South American tobacco, which is received in the form of cylindrical rolls two feet in length and one foot in diameter, made by rolling or twisting the tobacco leaves into a kind of rope about an inch or more in diameter, and then coiled up into these cylindrical rolls as the most compact and convenient form for transportation. We receive supplies from the Orinoco, Porto Rico, and from Maracaibo, and other South American ports. Roll tobacco is sent over in baskets made of twisted cane, called *canastras*. A considerable quantity of South American tobacco comes from the Brazils, both in the leaf and roll form.

TOBACCO BLOSSOM.

The tobacco of Cuba is considered to be the finest in the world: Havana tobacco makes the best cigars.

Asiatic tobacco.—Asia produces good tobacco, but mostly for her own consumption. The European market, however, gets the Persian or Shiraz, which is much esteemed. Tobacco is also received from the Spanish island of Manilla in the shape of fine cigars, which are manufactured there, and then exported. A little tobacco is sent from India, Ceylon, Java, and Sumatra. From Turkey, Latakia tobacco is imported, which consists of not only the leaf, but also the flowers and buds of the plant; it is so called after the Turkish province of Latakia (the ancient *Antioch*), where it is grown. Some considerable trade is carried on in the south of Europe with this tobacco, which is excellent and mild.

Nux Vomica (*Strychnos nux vomica*, L.; natural order, *Loganiaceæ*).—A medium-sized tree, with opposite, ovate, stalked, three to five-nerved, smooth, shining leaves, and greenish-white flowers; a native of the East Indies, very common on the coast of Coromandel. The fruit is a globular berry, about the size of an orange, and with a smooth, hard, yellow rind, containing five seeds embedded in the pulp. These seeds are circular, flattened, rather less than an inch in diameter, slightly concave, silky in appearance, and fawn-coloured, or light drab in colour.

Strychnine, the most energetic poison known, is procured from the bruised seeds of the *nux vomica*, which are imported from Coromandel and Ceylon. It is sometimes employed in cases of paralysis, and is much used as a poison for rats and mice. The annual imports now average about 250 tons.

IX. MISCELLANEOUS MEDICINAL PRODUCTS.

Aloes (*Aloe Socotrina*, Tournef.; natural order, *Liliaceæ*).—This drug is the bitter, resinous, inspissated or thickened juice which is obtained from the leaves of various species of arborescent aloes growing in tropical climates. The species belong to the lily family, and have very large succulent leaves. The leaves are cut off close to the stem, and so placed that the juice is drained from them into tubs; this juice is then boiled until it acquires the consistence of honey, and poured into gourds or calabashes, when it hardens into a black compact substance, having an aromatic smell and an exceedingly bitter taste.

There are four principal varieties of aloes in commerce:—1. *Socotrine Aloes*, the best, produced by the above-named species, and so called from the island of Socotra, on the south coast of Arabia, in the Indian Ocean. 2. *Barbadoes Aloes*—of a very fine quality, produced by *Aloe vulgaris*, which is indigenous to the English island of Barbadoes, and also to Jamaica, Arabia, and the east coast of Africa. The Barbadoes aloes is imported from Barbadoes or Jamaica, usually in gourds weighing from sixty to seventy pounds, but sometimes in boxes holding about half a hundredweight. 3. *Cape Aloes*—very inferior, which is the product of *Aloe spicata*; raised in large quantities at the Cape of Good Hope, and brought over in chests and skins, the latter being preferred. 4. *Caballine* or *Horse Aloes*. This is the poorest kind; it is generally the refuse of the Barbadoes aloes, and, from its very rank and fetid smell, can only be used in veterinary medicine.

In 1863 we imported 312 tons of aloes, valued at about £25,685.

Liquorice (*Glycyrrhiza glabra*, L.; natural order, *Leguminosæ*).—This is a perennial plant, having long yellow fibrous roots running deeply into the ground, with an herbaceous stem four to five feet in height, and alternate pinnate leaves; flowers blue, papilionaceous, disposed in axillary spikes. Liquorice is a native of Italy, Spain, Sicily, and the southern parts of Europe; but it has been successfully cultivated in England, even from the reign of Queen Elizabeth, especially at Pontefract in Yorkshire, and Mitcham in Surrey. The greatest portion of our supplies of that extract of the root which forms the common liquorice of the shops, is obtained from the Spanish provinces of Arragon, Catalonia, and Valencia. The juice, procured from the root by compression in a mill, is boiled slowly until it becomes of the proper consistence, and is then made into sticks or bars from six to eight inches long, which are usually covered with bay leaves, and imported under the name of Spanish juice. Liquorice in the form of paste, or of the root itself, is in common use as an emollient in catarrh or cough; the root is also much used by brewers in the manufacture of porter. About 560 tons of the root and paste are annually imported.

Ipecacuanha (*Cephalis ipecacuanha*, Rich.; natural order, *Cinchonaceæ*).—This is a perennial plant growing in Brazil, about five or six inches high. The roots are several inches long, contorted, greyish brown, annulated, and about the thickness of a goose quill. The root of this plant affords a very important emetic medicine. It is imported from Rio Janeiro in bales, barrels, and bags.

Rhubarb (*Rheum palmatum*; natural order, *Polygonaceæ*).—The well-known purgative is the root of different species of *Rheum* growing in Tartary and other parts of Asia. There are two sorts—viz., Russian or Turkey rhubarb, which is brought by the Chinese to Kiachta, and there cleaned and sent on to Moscow and St. Petersburg; and the East Indian or Chinese rhubarb, which is shipped from Canton to Europe. There are several other varieties in the market, but the above are the most generally employed in this country. We import annually about 140 tons.

Jalap (*Exogonium parga*; natural order, *Convolvulaceæ*).—This valuable purgative medicine derives its name from Xalapa in Mexico, where it is very abundant. It is a handsome climbing convolvulaceous plant with delicate pink flowers and a tuberose root. The tubers, varying in size from a walnut to an orange, are dark umber-brown in colour, and much wrinkled. They are imported either whole or sliced; and we receive from Mexico about 150 tons per annum.

Camomile (*Anthemis nobilis*, L.; natural order, *Compositæ*).—This is a well-known perennial plant, not unfrequent on dry, gravelly, or sandy heaths, and in the pastures of this country. The whole plant is intensely bitter, and an infusion of its flowers has long been esteemed as a tonic and stomachic, and used as an ingredient in fomentations. This plant is cultivated in England, and the flowers sold by druggists are the produce of the cultivated variety. Camomile flowers are also largely imported from France, Holland, and Germany.

Sarsaparilla (*Smilax officinalis*; natural order, *Smilaceæ*).—The rhizome of this plant is cylindrical, and the roots (the sarsaparilla of commerce), abounding more or less in starch, are as much as ten feet long. It grows on the slopes of the mountains, and is confined to South America, where it ranges from 20° N. to 60° S. latitude. Jamaica, whence so much

sarsaparilla is exported, does not produce any; the article known as Jamaica sarsaparilla is merely exported from the Spanish main for re-shipment. Sarsaparilla is imported in bales, and is known in the market as Lisbon or Brazilian, Honduras, and Jamaica or red sarsaparilla, of which the last is the most preferred. The imports in 1853 were 334,857 pounds.

Sarsaparilla is now regarded as a powerful alterative medicine in cases of physical debility. Its usefulness is daily manifested in the public hospitals, in cases of broken-down constitutions, so common to the class of patients by whom those establishments are frequented. It is chiefly used in rheumatic and cutaneous diseases. A concentrated liquid extract and a syrup are now prepared, which are the best forms under which it can be taken.

SENNA (*Cassia lanceolata;* natural order, *Leguminosæ*).—The senna of the shops consists of the leaflets of different species of *Cassia*, such as the one above, and also *C. obovata*, *C. acutifolia*, *C. elongata*, and *C. Æthiopica*—all small shrubs with simple abruptly pinnate leaves, and yellow flowers, growing in tropical Asia and Africa. True senna leaves may be recognised by their oblique lower edges, and the inequality of their insertion into the foot-stalk; their odour is very faint, but peculiar; and their taste is sweetish and nauseous. The following varieties are met with in commerce:—

LEAF OF SARSAPARILLA.

1. *Alexandrian Senna*, or the leaves of *Cassia lanceolata* and *C. obovata*. These plants grow in Upper Egypt and Arabia. The harvest commences in September. The branches of the shrub are cut, collected into bundles, dried in the sun, and then threshed until the leaves are separated from them. This process breaks the branches, and the leaves thus become mixed with portions of twigs. The senna leaves so obtained are then put into sacks and conveyed to the Nile, and carried down the river to Cairo and Alexandria. There they are unpacked, sorted, and repacked in large bales, and are then ready for the market.

2. *East Indian* or *Tinnivelly Senna*, the product of *Cassia elongata*, indigenous to Arabia and Africa, now cultivated in India, consists of long, thin, unbroken leaves of a yellowish-green colour. When good, it is fully equal to the Alexandrian.

3. *Tripoli Senna*, the product of *Cassia Æthiopica;* not held in much estimation.

X. MISCELLANEOUS PLANTS OF COMMERCIAL VALUE.

VEGETABLE IVORY—COROZO NUTS (*Phytelephas macrocarpa;* natural order, *Phytelephanteæ*).—The *Phytelephas*, twenty feet in height, resembles a dwarf palm, with a majestic tuft of pinnate leaves; it is a native of the low valleys of South America between 9° N. and 8° S. latitude, and between 70° and 79° W. longitude. Its nuts are enclosed in a large capsule about the size of a man's head, and, owing to the procumbent habit of the stem, often rest on the ground. The albumen of the nut is "at first a clear insipid fluid, with which travellers allay their thirst; afterwards this same liquor becomes milky and sweet," consolidating by degrees till it becomes as white and hard as ivory. The nuts themselves, under the name of Corozo nuts, are imported in large quantities, being used by turners in making a vast variety of trinkets and articles to imitate ivory. About 80,000 of these nuts were imported in 1852.

TONQUIN BEAN (*Dipterix odorata;* natural order, *Leguminosæ*).—The seeds of the Tongo tree, a native of Guiana, are the well-known Tonquin beans used to scent snuff.

OBJECT DRAWING.—II.

IN the last lesson we gave the plans of three blocks, placed in different positions in relation to the spectator. We now propose to show the method of drawing them.

Fig. 4.—First draw the square $a\,b\,e\,f$, representing the end of the object, which you will remember is vertical, and parallel to the edge of the table; and you must bear in mind also that you are to sit so that your chest is parallel with the table as well.

When you have decided as to the height of your eye in relation to the model, draw a horizontal line across your paper which shall have the same height in proportion to the square you have drawn as the real height of your eye has to the model; that is, supposing you see that your eye is three times the height of the model above its surface, then draw the horizontal line at three times the length of $a\,f$ above $e\,f$. In the illustration a different height is taken, the purpose being to cause the student to *use his own judgment* instead of merely copying the drawing. The line H L is thus the horizontal line.

Now, on referring to the plan given in the last lesson, you will see, that supposing a sheet of glass (the surface on which we draw being supposed transparent) to stand on D E, then the line $b\,c$ of the model (Fig. 3 [1]) would be at right angles to it; and it has already been shown that in drawing, all such lines should converge to the point of sight.

Therefore from b (Fig. 4) draw a line to P S, and as all the long edges of the model are parallel, the same rule would affect them equally; therefore draw lines from e and f to the point of sight.

Portions of these convergent lines will, as you can easily understand, form the edges of the solid, and you must terminate them by the perpendicular $g\,h$ and the horizontal $h\,i$.

For reasons already mentioned, it is not intended to give in this place any rules for obtaining the distance of $g\,h$ from $b\,e$. You must accustom yourself in object drawing to use your judgment, and you will, with but very little practice, be able to form a tolerably just idea of the distance; for you will see that if the lines had been drawn at either of the places indicated by dots, the object would, in the one case, appear merely as a flat piece of wood, whilst in others a balk of timber would be represented.

The plan (Fig. 3 [2]) of the next figure will show you that in this figure the length of the block is parallel to the picture-plane, the narrow edges receding. To begin this representation (Fig. 5), draw the rectangle $b\,e\,h\,g$, $b\,g$ being double $b\,e$.

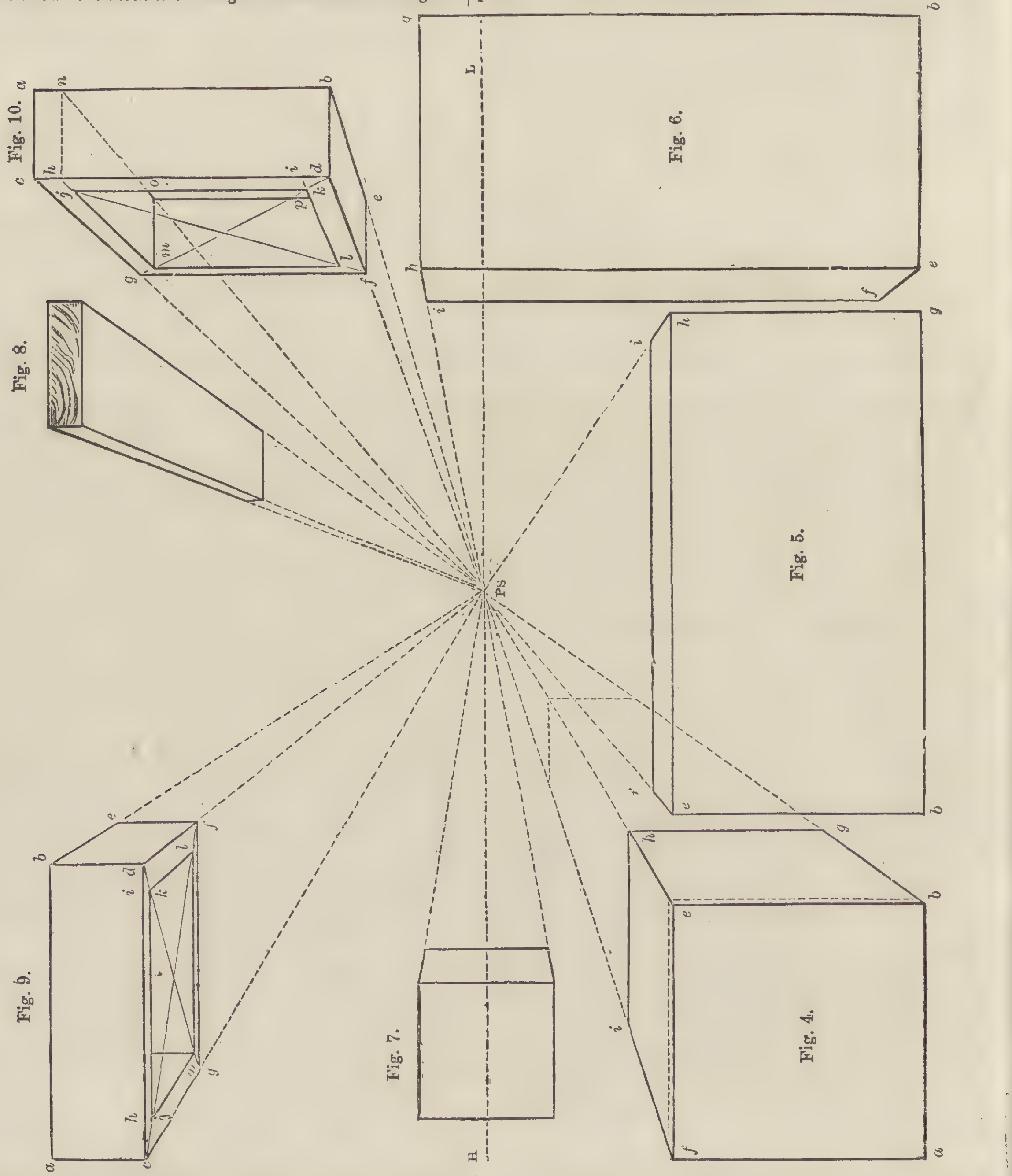
Now you will at once perceive that, as the block is immediately in front of you, you would not see either its left or right side, but only the top. On referring to the last view, you will be reminded that the ends $a\,b$, which in that case were parallel to the picture, are now at right angles to it. Therefore from e and h draw lines to the point of sight, then the line $f\,i$ parallel to $e\,h$ will complete the top, and the figure will thus show the front and top only.

Now proceed to sketch Fig. 6, which is the view of the block when standing on its end on your right side. Here, again, as the face is parallel to the picture, the front consists of the rectangle $b\,e\,h\,g$. Having completed this, draw lines from e and h to the point of sight. Then the perpendicular $f\,i$ will complete the view, which will consist of front and side only; for as the end $h\,g$ is higher than the horizontal line, you would not be able to see the top. Of course, you will understand that all the blocks need not necessarily be the same size—in fact, as you are placing your height at three times that of the square end, it will be necessary that this last one should be longer than the others, for as the length of the two already drawn is only twice their width, the end would still be below the horizontal line; but, as already stated, whatever may be the proportions of the

objects, and whatever the height of the spectator, the principles here laid down will apply, and a very small amount of practice, guided by patient and intelligent observation, and urged on by the desire to learn, will soon enable you to judge whether your drawing truly represents the object as you see it.

Fig. 7 shows the mode of drawing a cube or other rectangular

the eye of the spectator (supported or suspended by means not shown in the drawing). It will be evident that, as the long edges of the plank are at right angles to the end, they will run directly from it into the distance, and must therefore be drawn to the point of sight, the lines forming the distant end being parallel to those seen in the front.



object when it is absolutely on a level with your eye, so that you do not see either the top or bottom of it; but as it is on your left hand you can see its right side. Of course, if it were placed immediately opposite to your eye—namely, in front of the point of sight, you would only see the front, but neither top, bottom, nor sides.

Fig. 8.—The object here represented is a plank, the *end* of which is parallel to the picture-plane, and the length at right angles to it—the whole object being placed *above* the level of

Fig. 9.—This object consists of four pieces of wood mitred together so as to form a piece of framing, or the sides of a shallow box.

Here, again, the side $a\ b\ c\ d$ which is parallel to the front is to be drawn of its proper dimensions, and this being done, lines are to be drawn from each of the angles to the point of sight. The lines $e\,f$ and $f\,g$ will then complete the general view of the object as it would appear if it were a solid block.

It is necessary here to call your particular attention to this

plan of drawing the *general* outline of the whole object before attempting the detail.

It must be evident that the entire of the interior lines, and all the detail, must depend upon the outline of the object *as a whole*, and therefore this system is impressed upon you.

The under surface of this slab, then, although in reality a *square*, will in your drawing be represented by the irregular four-sided figure $c\,d\,f\,g$.

Draw the diagonals $c\,f$ and $d\,g$.

Now from c and d mark off on the line $c\,d$ the distances $c\,h$ and $d\,i$, equal to the thickness of the pieces of wood of which the object is made, and from these points, h and i, draw lines to the point of sight.

The line drawn from h will cut the diagonals in j and m, and the line drawn from i will cut the diagonals in k and l.

Draw a line from j to k, and another from m to l; strengthen the lines $j\,m$ and $k\,l$; then the figure $j\,k\,l\,m$ will represent the inner square or inner edge of the wood of which the framing is formed.

The perpendicular at m represents the vertical junction of the inner sides of the framing. This completes the sketch, which may now be "lined in"—that is, nearly rubbed out, and the lines repeated in a clear and decided manner, remembering that in object drawing you ought not to use either rules or compasses.

Fig. 10 is a view of the same object when placed vertically and on your right-hand side.

The same lettering has been retained, and this will guide you in sketching the frame up to the stage shown in the last figure; but the present study is an advance on the previous one, for this is so placed that you can see through it; and it is therefore necessary to find the width of the distant side, which, although known to be the same as the near one, will of course appear diminished by its being removed from the front of the picture.

From h draw $h\,n$, which is of course the real width of the side, and from n draw a line to the point of sight.

Now from m draw a horizontal line which will cut this last line in o; then $m\,o$ represents the length of $h\,n$ when thus far removed from the plane of the picture.

Draw the perpendicular $o\,p$; strengthen as much of $n\,o$ as is visible, and the sketch of the object will then be completed.

SEATS OF INDUSTRY.—X.

BELFAST.

BY WILLIAM WATT WEBSTER.

BELFAST, the capital of Ulster, the chief centre of commerce and industry in Ireland, and the metropolis of the linen trade and manufactures of the United Kingdom, is a town of comparatively modern origin, situated at the point where the river Lagan discharges its waters into Belfast Lough, or Carrickfergus Bay, about twelve miles from the Irish Sea, and a hundred miles from Dublin. The name Belfast is said to be a corruption of *Bela-fearsad*—*i.e.*, the town at the mouth of the river; but it need hardly be stated that this derivation is disputed, and that a variety of others have been suggested. The ground on which Belfast is built was reclaimed from the sea, and the greater portion of it does not stand more than six feet above the high-water mark. Owing to this cause it is occasionally visited by inundations and epidemics, but otherwise it is not by any means an unhealthy town, and in many respects it is most advantageously placed. Belfast Lough is a capacious bay, twelve miles in length and five miles broad at the entrance, affording safe anchorage for vessels of the largest size; while in the Pool of Garmoyle, four miles from Belfast, loaded ships float safely within a short distance of dry land. This estuary is protected from the westerly winds, which are the most frequent in that quarter, by a fine range of hills to the west, some of which are upwards of 1,000 feet high, and by the mountain of Divis to the north-west, which rises 1,567 feet above the level of the sea. The landward environment of Belfast is, indeed, exceedingly beautiful and picturesque. The northern shores of the bay are studded with elegant villas, and on an elevation to the south stands the aristocratic suburb of Malone, while the whole neighbourhood of the town is adorned with pleasing residences and pretty villages. From the flatness of the site the general aspect of Belfast, as seen from a distance, is not striking; but it contains many broad, straight, well-paved and well-lighted streets, and a large number of tasteful and expensive private mansions and public buildings. The mercantile quarter of the town lies on and near the quays that extend for about a mile below Queen's Bridge, which connects Belfast with the suburb of Ballymaccarrett, in the county of Down. The manufactories are chiefly situated on the rising grounds on the north and west sides of the town. Belfast can boast of a large number of excellent educational institutions and facilities, among which may be mentioned Queen's College, a picturesque pile of brick and stone in the Tudor style, opened in 1849; the Botanical Gardens, adjoining the College grounds; a Museum; the Royal Academical Institution, founded in 1810, which possesses a collegiate character, supporting professors in all branches of science, classics, and general literature; and the Belfast Academy, which at one time had a high classical reputation. The most celebrated public edifices are the White Linen Hall in Donegal Square, built in 1785, and the Commercial Buildings, an extensive block of houses at the south end of Donegal Street, erected in 1822, comprising a hotel, a news-room, an assembly-room (also used as an exchange), and various descriptions of offices.

Nothing is known regarding Belfast earlier than the twelfth century, at which date there appears to have existed a fortified station near the mouth of the Lagan. For a long period the town consisted of a few houses, a church, and a castle. Before the beginning of the fourteenth century, however, the place must have grown to considerable dimensions, and become of no small importance, for in 1316 the town and castle of Belfast were attacked and destroyed by Edward Bruce, and nearly two centuries elapsed before they came again into possession of the English. In the time of Henry VIII., Hugh MacNial Oge obtained a grant of the town and castle on certain conditions, which either he or his successors failing to fulfil, they reverted to the Crown. Randolphus Lane occupied the castle during the earlier part of the reign of Queen Elizabeth, but later on that sovereign appears to have conferred the castle and lands on Sir Thomas Smith, he undertaking to maintain a troop of horse and a company of foot for her Majesty's use, and to answer the royal summons when called upon. About the year 1604 Smith violated the conditions of the grant, and the reigning sovereign, James I., bestowed the castle and lands on Sir Arthur Chichester, the Lord Deputy, whose descendants continue to enjoy the lordship. Belfast increased rapidly after this transfer, and in the fifth year of the same king it obtained a charter of incorporation, which was renewed by James II., erecting it into a municipal and parliamentary borough, with the franchise vested in a sovereign or mayor, twelve burgesses, and a commonalty, and with the privilege of sending two members to the Irish Parliament. About this time many Scotch and English families were settled in the town and neighbourhood, in connection with the project of James I. for the formation of an English plantation in Ulster; and on the abolition of the port monopolies of Carrickfergus, in 1637, Belfast became the principal commercial depôt of the Plantation, and the seat of the Custom House. "At that era," says a writer in the "Encyclopædia Britannica," "commenced the first signs of the future progress of Belfast. The great influence exerted by this infusion of new blood into the district is attested at the present time by the persistency of the lowland Scotch dialect and accent, the prevalence of the Presbyterian religion, and the physical characteristics of the people, no less than by their commercial activity, industry, and enterprise." The progress of the town was suspended during the civil war, the inhabitants having first espoused the cause of the Parliament and afterwards that of the King. It was the expression of the feelings with which the Presbyterians of Belfast regarded the execution of Charles I., that drew upon the town the sarcasm of John Milton, who, it will be remembered, said, "Presbyter is but old Priest writ large." The secretary of Cromwell, in his "Observations upon the Articles of Peace with the Irish Rebels, etc.," dated 1649, described Belfast as "a small town in Ulster," "a barbarous nook in Ireland," and "a place better known by the name of a late barony than by the fame of these men's doctrines or ecclesiastical deeds, whose obscurity till now never came to our hearing." The zeal of the inhabitants of Belfast for the cause of civil and religious liberty

led them to support the Prince of Orange against James II., and to proclaim him king, and their decisive action at this crisis was duly rewarded. William visited the town in June, 1690, shortly before the march to the Boyne, and so highly gratified was he with his reception, that he granted £1,200 per annum from the State coffers to the Presbyterian Synod of Ulster. This grant, afterwards increased and called the *Regium Donum*, was ordered to cease in 1869. After the Act of Union the municipal government of Belfast was modified by the addition of police and life commissioners to the former corporation, and this constitution continued till the passing of the Municipal Reform Act in 1841, when the present corporation, consisting of a mayor, ten aldermen, and thirty town-councillors, was instituted. From the time of the Union till the Reform Bill of 1832, Belfast returned one member to the Imperial Parliament, but by that Act the borough obtained two representatives.

Belfast is mainly indebted to the cultivation of linen manufacture for its importance and prosperity, and it has justly been styled the modern Panopolis, that, according to Strabo, having been the name of the principal centre of the linen manufacture of the ancients. Flax was grown and exported from Ireland, its fibre was spun and manufactured into cloth, and its seed crushed for oil in very early times. The old Irish or Celtic name for flax was *lhin*, and the term *poll a lhin*, still applied to certain places in the country districts, proves that the steeping of flax in pools was practised in Ireland at a very remote period. It is even considered probable that linen may have been introduced into Ireland by the Phœnicians. From the fragments of the Brehon laws which are still extant, it appears that the ancient rulers of the Irish tribes, who promulgated their decrees in the open air on the hill-tops, admonished the Brughaids, or farmers, to learn the art of cultivating and manipulating flax. In his "Annals of Commerce" Macpherson says, "We learn from chronicles that about A.D. 500 fine linen was possessed by the inhabitants of Britain and Ireland. The bodies of the dead, at least of those of rank, were wrapped in it." But it is doubtful whether linen was extensively or generally manufactured in Ireland before its conquest by England in 1170; for in the list of exports given by Giraldus Cambrensis no linen manufactures are mentioned. Ireland had, however, an export trade in linen goods in the thirteenth century; for it can be proved that Irish linen was used at Winchester about 1272, during the reign of Henry III. In the middle of the fifteenth century reference is also found to linen imported into England from Ireland; and Leland states, with respect to Liverpool, about the year 1545: "Yrisch merchants cum moch thither, and moch Yrisch yarn that Manchester men do by there." Upwards of a century later, or about 1670, according to Macpherson, linen manufacture "began among the Scots in the north of Ireland, where it has to this day flourished more than in any other part. The vast quantities of linen which England takes of the Irish, enables them to pay for almost every kind of product and manufacture which we supply them with. Before they made much linen cloth, the people of the north of Ireland sent their linen yarn to England."

It was for a long period the favourite policy of English statesmen to settle foreigners in Ireland, and to establish new trades and manufactures. Sir Henry Sidney, the wise Lord-Deputy of Ireland in the reign of Queen Elizabeth, and the father of Sir Philip Sidney, in a letter to Sir Francis Walsingham, says: "I caused to plant and inhabit about forty families of the reformed churches of the Low Countries, flying thence for religion's sake, in one ruinous town called Swords; and truly, sir, it would have done any man good to have seen how diligently they wrought; how they re-edified the quite spoiled old castle of the same town, and repaired almost all the same; and how goodly and cleanly they and their wives and children lived. They made diapers and ticks for beds, etc." The Earl of Strafford, when Chief Deputy in the reign of Charles I., vigorously and successfully followed up this policy, bringing over flax-seed from Holland, and inviting French and Flemish artisans to settle in Ireland, and prosecute the cultivation of flax and the manufacture of linen cloth. Whatever may have been the motives that actuated the unfortunate statesman—and he certainly was not a disinterested benefactor of Ireland, for he tried to turn the improved industry into a personal monopoly—he deserves to be remembered for the impetus he gave to the linen manufactures of Ireland. The earl invested £30,000 of his private fortune in the enterprise, and it was afterwards made one of the grounds of his impeachment that "he had obstructed the industry of the country by introducing new and unknown processes into the manufacture of flax." The Duke of Ormond also distinguished himself by the encouragement he gave to foreigners possessed of skill in linen manufacture to settle in Ireland; and two years after the Restoration he pushed a bill through the Irish Parliament, entitled "An Act for Encouraging Protestant Strangers and Others to inhabit Ireland," which duly received the royal assent. In his "Miscellanies," first published in 1681, Sir William Temple says, "No women are apter to spin linen thread well than the Irish, who labouring little in any kind with their hands, have their fingers more supple and soft than other women of the poor condition amongst us; and this may certainly be advanced and improved into a great manufacture of linen, so as to bear down the trade of France and Holland."

Notwithstanding all that had been done since the time of Elizabeth, however, the total annual value of the linen cloth exported from Ireland at the accession of William III. did not amount to £6,000. Before the passing of the Act of 1697, William invited Louis Crommelier, a Huguenot refugee then settled in Holland, to undertake the office of Royal Superintendent of Linen Manufactures in Ireland. Crommelier belonged to a family which had carried on linen manufacture in France, in all its branches, for upwards of four hundred years, and he himself had upwards of thirty years' experience. In 1698 he arrived in Ireland, accompanied by his son, and selected the ruined village of Lisnagarvey as the site of the new government manufacturing establishment A little colony of refugees, of all ranks and many trades, soon became planted at Lisburn, which is about seven miles from Belfast, and the place quickly began to wear a prosperous aspect. Many other colonies of French and Flemish artisans were established in the south of Ireland, where they carried on various branches of industry, but only those in the north were permanently successful, although Cork, Limerick, and Waterford enjoyed superior facilities for trade. Among the French settlers in the north of Ireland may be mentioned Peter Goyer, a Picardy manufacturer, who began the manufacture of silk and cambric at Lisburn.

At that time woollen goods were the staple manufacture of Ireland, and the prosperity of the trade soon roused the jealousy of English rivals. Protection was not an economic heresy in those days. The importation of yarn and linen and woollen goods from France was strictly prohibited, and at one time it was a penal offence to wear French cambric. These restrictions were, of course, believed to be beneficial to the people of England, and the same arguments which excluded French manufactures from the English markets were used to exclude Irish woollens. In 1698 the English House of Peers memorialised King William to use his influence to discourage the woollen manufactures of Ireland, and, by way of recompense, "to encourage the linen manufactures of the said kingdom, pursuant to an Act of Parliament in the year 1696." The English House of Commons also addressed the king, requesting him to induce the Irish "to cultivate the joint interest of both kingdoms; and that as Ireland is dependent on and protected by England in the enjoyment of all they have, they would be content to apply themselves to the linen manufacture, whereby they would enrich themselves and be beneficial to England at the same time." The king replied, "I shall do all that in me lies to discourage the woollen manufacture in Ireland, and to encourage the linen manufacture, and to promote the trade of England;" and the Irish Legislature immediately imposed heavy duties upon the export of all woollen cloths. As a matter of course, the woollen manufacturers were completely ruined; thousands of families were forced to emigrate, their labour and skill being no longer required; and in the south and west whole districts were nearly depopulated. In 1699 an Act was passed for the special encouragement of the Irish linen trade, and a board called "The Trustees for the Linen and Hempen Manufactures" was established at Dublin, for the purpose of fostering the growth of linen manufacture in the north of Ireland. At first an annual sum of £6,000 was placed at the board's disposal; but afterwards its revenue was increased to £20,000, and at this sum it remained for a long period. The money was

spent in premiums for the growth and importation of flax-seed for the cultivation and preparation of the largest quantities of flax-fibre, for the invention and distribution of new and improved implements, for the erection of scutch-mills, and for the production of the best qualities of yarn and cloth. A number of officials were appointed in the localities where the manufacture was carried on, and inducements were held out to the skilled weavers and flax-dressers of foreign countries to settle in Ireland. This board continued in existence till the year 1828, when it was finally abolished.

In his "Dictionary of Commerce," Mr. McCulloch makes the following criticism on the mistaken policy which successive governments so long pursued, in reference to the Irish linen trade. "For a long period," says this able economist, "previous to 1830, bounties were granted on the exportation of linen. In 1829, for instance, notwithstanding it had been greatly reduced, the bounty amounted to £300,000, or to nearly *one-seventh* part of the entire real or declared value of the linen exported that year. It is not easy to imagine a greater abuse. A bounty of this sort, instead of encouraging the manufacture, rendered those engaged in it comparatively indifferent to improvements; and though it had been otherwise, what is to be thought of the policy of persisting for more than a century in supplying the foreigner with linens for less than they cost? We have not the least doubt that were the various sums expended in well-meant but useless attempts to force this manufacture, added together with their accumulations at simple interest, they would be found sufficient to yield an annual revenue little, if at all, inferior to the entire value of the linens we now send abroad. And after all, the business never began to do any real good, or to take firm root, till the manufacture ceased to be a domestic one, and was carried on principally in mills, and by the aid of machinery—a change which the old forcing system tended to counteract. The only real and effective legislative encouragement the manufacturer ever met with, has been the reduction and repeal of the duties on flax and hemp, and the relinquishing of the absurd attempts to force their growth at home." But it is to be feared that the discouragement of the woollen trade, and the encouragement of the linen manufactures, were intended to serve another object than the obvious one. The woollen trade was principally carried on by the Roman Catholics in the west and south of Ireland, while Protestant Ulster was the chief seat of the linen manufacture; and by favouring the latter, and destroying the former industry, the Government of King William probably thought it was propagating Protestantism and checking Popery.

Previous to the introduction of machinery, Belfast was but a small town; its population in 1760 being less than 9,000. Cotton-spinning machinery was first used in the town in 1777, and machinery for the spinning of flax in 1806; and about the year 1792 shipbuilding was added to its industries. The progress Belfast made after the first-mentioned of these dates was rapid and steady. In 1798 the population numbered 18,320; in 1831, 48,224; in 1841, 75,308; in 1851, 100,300; and in 1861 it was returned at 119,718, of whom 40 000 were Roman Catholics.

It was not till 1824 that the idea of erecting a spinning-mill on an extensive scale was entertained by a body of the Belfast linen manufacturers, and the project was not carried into execution till 1828. In that year the Messrs. Mulholland built their works, which are in active operation at the present day, and since then an extraordinary extension of machinery has taken place. The linen exported from Belfast in 1835 amounted to 53,881,000 yards, and was valued at £2,694,000, and in 1863 the *Linen Circular* calculated the aggregate value of the linen manufactured in Belfast and its suburbs during that year at £10,000,000. In 1864 the total imports into Belfast amounted to upwards of £10,000,000, and the exports were stated at a total of £8,000,000. There were in the town and neighbourhood of Belfast in the year 1858 thirty-three steam spinning-mills, or about one-half of all the steam spinning-mills then in Ireland, which numbered seventy-six. In Ure's "Philosophy of Manufactures" (1861) it is stated, that "of the Irish flax factories thirty-nine, or nearly one-half, are situated in Belfast and its environs, and outside the province of Ulster there are but nine." Mr. A. J. Warden, the author of the "History of the Linen Trade," has remarked that there is a decided tendency to centralise the linen trade in Belfast. "Many of the eminent houses," he says, "have opened sale-rooms in Belfast, at the same time conducting their operations as formerly in the localities where their manufactories and bleach-fields are." During the past four years the linen trade in the north of Ireland has been rather depressed, and in 1870 it was injuriously affected by the outbreak of the war between France and Germany. In the autumn, however, the exports to the United States were very large, and nearly, if not quite, compensated the loss of custom from Germany and France.

The commerce of Belfast is very extensive and rapidly increasing. Only a comparatively small part of the exports are sent direct to foreign countries, and the most important branch of traffic is across the Irish Channel to Great Britain, and principally to Liverpool. About forty steamers are regularly engaged plying between Belfast and the principal ports of England and Scotland, besides Dublin and Derry, and the chief articles of export are linen and cotton manufactures, linen yarn, corn, meal, flour, provisions (including under that term hams and bacon), tow, and horses. The increase that has taken place in the shipping of the port is, indeed, quite as remarkable as the growth of the manufactures. In 1700 there were only five small vessels owned in Belfast, while in 1865 there were 326 sailing vessels over 50 tons burden, and 153 below 50 tons, besides 11 steam-ships belonging to the port; and considerably over 8,000 vessels, with an aggregate of about 1,250,000 tons burden, are now annually entered and cleared at the port. The inland trade of the town is carried on by means of the Lagan, a canal, and three railways.

There are five extensive cotton-mills in Belfast, in which velvets, fustians, jeans, ticking, ginghams, calico, muslins, etc., are made. Besides the industries already noted, calico-printing, bleaching, and dyeing are carried out on a large scale in Belfast, and it also contains important iron foundries, machine shops, chemical works, glass works, distilleries, breweries, flour-mills, tanneries, roperies, etc.

The climate and soil of Ireland are more favourable to the growth of flax than the climate and soil of either of the sister kingdoms, and a society has long been established at Belfast for promoting its cultivation. This society has not been uninfluential, but it is considered doubtful whether its exertions have been beneficial to the country. In 1847 there were only 58,312 acres of land under flax in Ireland, while the average acreage during the three years 1865, 1866, 1867 was returned at 256,015. Nearly the whole of the flax grown in Ireland finds its way to Belfast. The condition of the working classes in Belfast will compare favourably with that of the artisans of any other town in the kingdom, and in some respects they are better off, for they seldom suffer from temporary interruptions of trade; while the landed aristocracy are in a small minority, and the middle classes enjoy all the comforts and many of the luxuries of life.

TECHNICAL DRAWING.—XXXI.

DRAWING FOR MACHINISTS.

THE STEAM-ENGINE (*continued*).

Fig. 284 is the crank-pin that is held by a cotter, or wedge, in the smaller end of the crank, and it receives the larger end of the connecting-rod (Fig. 285), which end consists of a solid square-shaped block, through which passes a gib and cotter. The brass bearings, or "brasses," are held in position by a strap which passes over them, and are kept from opening by the gib, and tightened by the cotter: a small set-screw, with hexagonal head, holds the cotter in position when driven into its place.

The smaller end of this connecting-rod (Fig. 286) is made differently, for it passes inside the closed jaws of the motion-block (Fig. 312), and the brasses need no flanges to prevent their coming out of place. This end is made solid without any strap, and the brasses are tightened up by a cotter and screw, no gib being required. Other forms of connecting-rods are in common use, the kind generally adopted for marine engines being shown in Fig. 219 (Vol. I., page 325).

Figs. 287 and 288 are end elevations of the connecting-rod, and Fig. 289 a section across the middle to show its thickness.

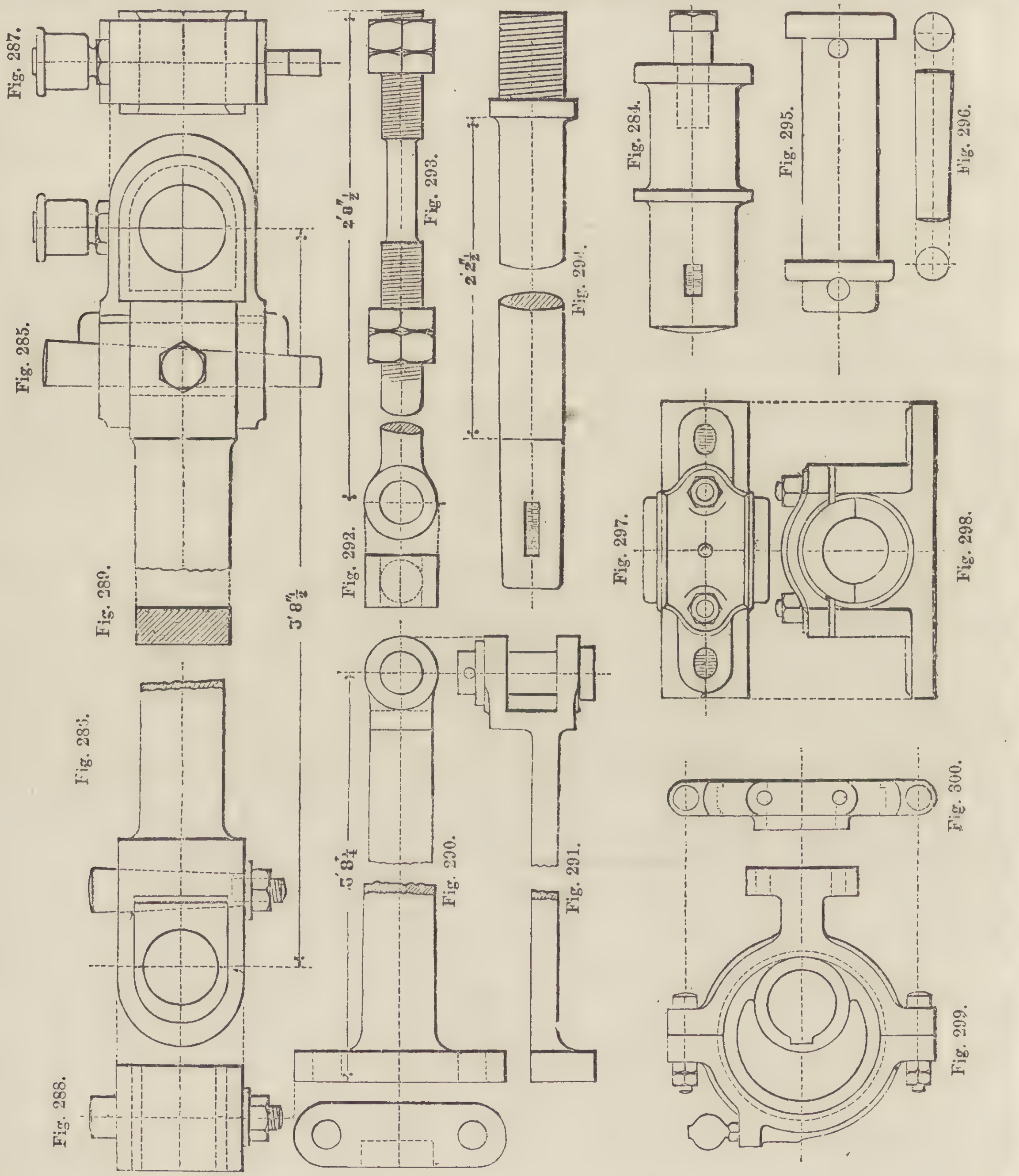
Figs. 290 and 291 are views of the eccentric-rod, which is merely a smaller and lighter connecting-rod between the eccentric and slide-valve. Both connecting-rod and eccentric-

rod should be as long as possible, because if too short they cause an irregular distribution of steam in the cylinder, and injurious pressure upon the slide-bars.

Figs. 292 and 293 are views of the valve-rod, which enters through a gland in the valve-box cover, and holds the slide-valve, its outer end being in connection with the eccentric-rod, and thus the movements of the eccentric are communicated to the slide-valve. The screw upon this valve-rod is provided with double sets of nuts, the outer, or second one, being called a lock-nut, and its office is to hold the inner ones in any desired position. When adjusted into its place, the outer nuts are screwed fast upon those inside, preventing them from becoming loosened easily. Wherever there is much vibration, single nuts are liable to loosen, and lock-nuts form a simple, cheap, and most effective method of preventing this evil. The centre portion of the screwed end is turned smaller, so that the inner nuts may slip over it, and thus be more expeditiously inserted than if they had to be screwed along the whole length.

Fig. 294 is the piston-rod, partly shown with the piston in Fig. 275. This rod is made of steel, for it has to endure much friction, and would wear away if made of iron. One end is screwed into the piston, and the other conical end fits into a corresponding hole in the motion-block (Fig. 312), and is fastened by a cotter into its position there.

Fig. 295 shows the motion-block pin, which forms a bearing for the smaller end of the connecting-rod (Fig. 286), and is inserted through a corresponding hole in the motion-block (Fig. 312). A small piece of wire is inserted close under the head of



this pin, and fitting into a keyway in the motion-block, prevents the pin from turning round, and compels the brasses of the connecting-rod to move upon it.

As any pressure on the piston causes a side strain to the cylinder, pedestals, etc., which the bolts alone are unfitted to withstand, the steady-pin (Fig. 296) is a very simple, cheap form of key to hold all the parts in their proper position in spite of side strains. Holes are drilled through the cylinder and pedestal flanges, and these conical pins are driven in and form a most effective key, which is easily removed when necessary for taking the engine to pieces.

Figs. 297 and 298 are a plan and elevation of the plummer-block or pedestal, which carries the hinder end of shaft near the fly-wheel.

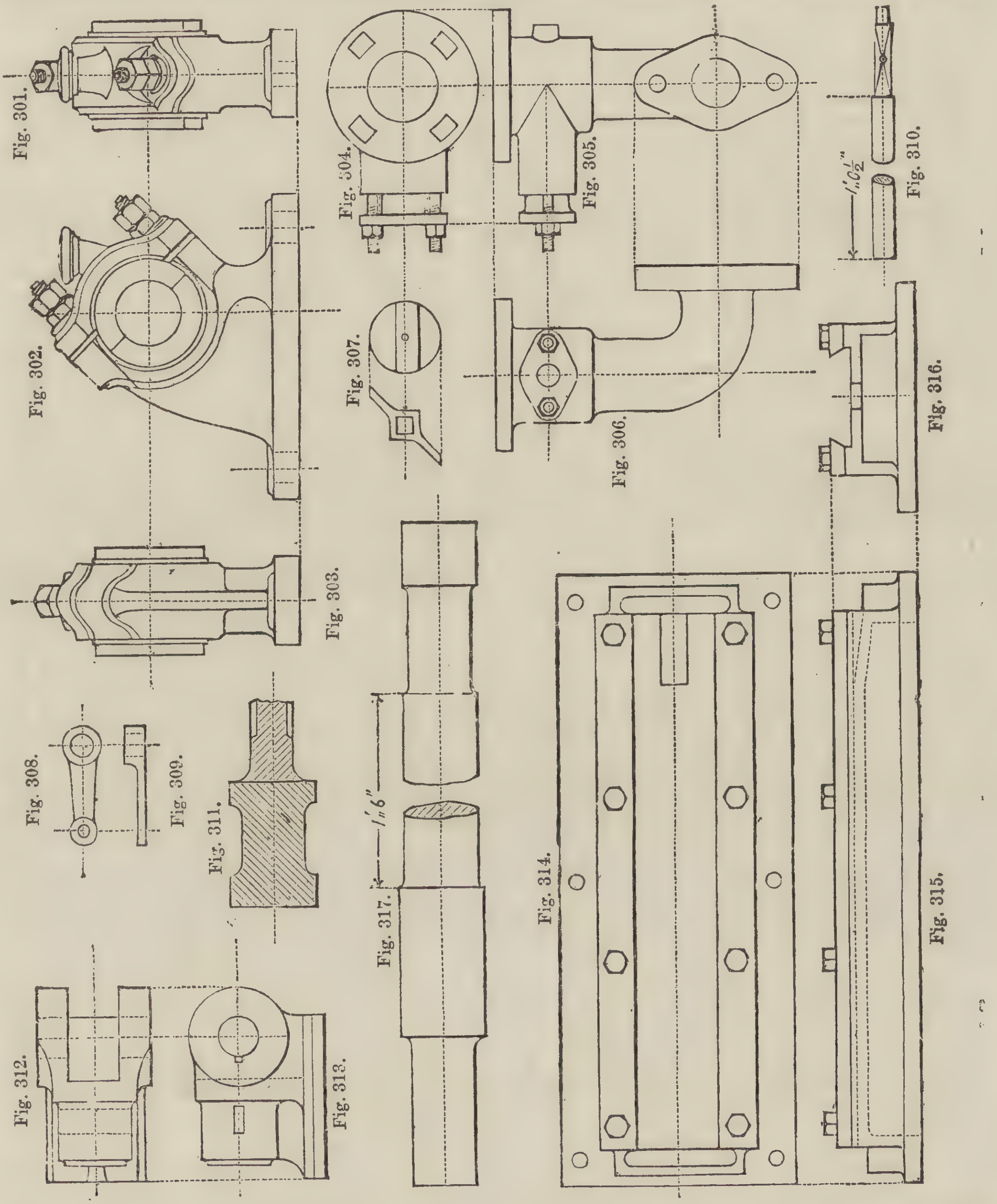


Fig. 301. Fig. 302. Fig. 303. Fig. 304. Fig. 305. Fig. 306. Fig. 307. Fig. 308. Fig. 309. Fig. 310. Fig. 311. Fig. 312. Fig. 313. Fig. 314. Fig. 315. Fig. 316. Fig. 317.

Fig. 299 and 300 are two views of the eccentric which moves the slide-valve, as already stated in the preceding lesson. An eccentric is nothing more than a disguised form of crank, where what corresponds to the pin is sufficiently large to embrace the shaft. Its movements are the same as those of a crank, and it forms an excellent method of moving the valves of steam-engines. The central portion is keyed on the main shaft, and the two rings placed around it are held in position by bolts with locked nuts. A small oil-cup behind serves to keep the working surfaces lubricated.

Figs. 301, 302, and 303 are front, side, and back views of the oblique pedestal behind the crank. As the pressure of the piston is altogether from the side, such a pedestal as Fig. 298 would wear away at the joints of the brasses without the means

of tightening, and therefore in this case would be unsuitable; but the side pedestal shown is properly arranged for resisting the pressure communicated to the crank, and being tightened up as it wears.

Figs. 304, 305, and 306 represent the throttle-valve pipe in three views; Fig. 307 the valve itself; and Figs. 308, 309, and 310 its lever and shaft. This contrivance is really an imperfect form of valve or tap, which, closing, reduces the quantity of steam admitted to the cylinder. It is worked by the governor, in the manner shown in Figs. 338, 339.

Fig. 311 is a section of the fly-wheel rim and one of its arms; side elevations being shown in Figs. 338 and 339.

Figs. 312 and 313, the motion-block, which forms a connection between the piston-rod and connecting-rod; and also works in the slide-bar (Figs. 314, 315, and 316). An inspection of the general drawing will show that the angular direction of the connecting-rod would strain the piston-rod, unless means were adopted for resisting it. The motion-block slides upon a smooth surface parallel with the axis of the cylinder, and receives the angular thrust of the connecting-rod, so preventing any undue strain coming upon the piston-rod. There are many different forms of slide-bar in use, but the one shown is as neat in appearance as any, though it has a disadvantage in offering a larger surface for pressure below than above, for the engine to run round to the right—that is, in the direction that the hands of a watch turn—and then the pressure on the motion-block is always downwards.

The fly-wheel shaft (Fig. 317) is shown as if partly broken, the object being to represent its special form to as large a scale as possible, without occupying inconvenient space on the page by mere length. It will be observed that the corners are rounded instead of being made square. This is a most important feature in shafting exposed to any strain, for when the angles are made square, shafts will sometimes break, although amply strong enough in appearance for the work to be borne.

CHEMISTRY APPLIED TO THE ARTS.—IX.

BY GEORGE GLADSTONE, F.C.S.

CANDLE-MAKING.

WONDERFUL progress has been made during the last few years in the art of making candles; those which are now in common use in the best circles being of a composition wholly unknown to the last generation. The article used almost universally by the lower orders remains, however, much the same as it then was. For certain purposes the old-fashioned dips are not superseded. In the first place they are cheap, and in the second they are not liable to gutter, which renders them most appropriate when a candle is to be carried about: the readiness with which some of the superior sorts of candles shed the melted portion while being carried about a house is often a source of great annoyance, and cause of damage to the carpets and other articles of furniture. The necessity of snuffing the dips is, however, an objection, as they give only a very indifferent light in the interval, and if not attended to, the burnt portion of the wick is apt to fall and cause waste.

Tallow candles belong to two categories—*dips* and *moulds*. The latter are superior to the former, both in composition and appearance, though actually made of the same materials. The tallow used for such purposes often contains a mixture of various fats, such as those of beef and mutton, hog's lard, etc. Such ingredients are liable to turn musty and rancid, on which account it is necessary to purify them, first by melting them and straining off all the membranous substances which may be mingled with them, and subsequently boiling the fat up with a little water and sulphuric acid. If mould candles are to be made, the tallow is generally subjected to other processes in order to increase the firmness, and at the same time to improve the colour. Pressure is sometimes used to separate the more liquid portion; but alum, borax, and other substances are also often mixed with the fat in order to clarify and harden it.

The wick of a tallow candle needs to be rather bulky and loose in texture, so as to allow the melted tallow to rise freely: cotton, loosely twisted, fulfils these conditions best. A wick which will not require snuffing can be made by plaiting the thread tightly, because in such case the wick will never keep straight as it burns, but will curl up until the end projects to the outer edge of the flame, where the heat is sufficiently intense to burn away the carbon altogether. Such wicks, however, will not absorb sufficient tallow to produce a satisfactory light, and are therefore reserved for the better descriptions of candles, which burn with a much brighter flame. For large candles two wicks are sometimes used, and they are so placed that they bend in opposite directions as they burn, and thus produce a broader illuminating surface.

To make *dips*, the wicks are attached to a frame, and immersed in a trough of molten fat, from which they are gradually withdrawn, to allow the adherent tallow to cool. This dipping is repeated from time to time until the candles have acquired the proper thickness, the subsequent dippings after the first being more rapidly performed, and in tallow of a rather lower temperature.

Mould candles suggest by their name the plan adopted in their manufacture. The mould consists of a metallic tube of the proper shape and size, through which the wick is passed, and then the molten tallow is poured in and left to cool. A large number of these moulds are arranged in one frame, so that they are all filled at one operation. Pewter is found to be the best material of which to make the moulds, as it is not affected by any acid there may be in the tallow. They should not be made any thicker than is necessary for the sake of durability, as the thinner they are the more rapidly will the cooling take place.

Sperm candles are much superior to the moulds, and until within a comparatively recent period were the only rival of the real wax candle. The name is simply a contraction for spermaceti, the article from which they are principally made. It is a kind of fat which is obtained from the head of a particular species of whale, *Physiter macrocephalus*, which, when the oily portion is expressed, forms a solid of pearly whiteness and of crystalline structure. It does not contain any glycerine, and hence it is not greasy to the touch. For this reason, as well as their beautiful appearance and high illuminating power, sperm candles have justly enjoyed a high reputation. In order to free the spermaceti thoroughly from the oily portion, pressure is not found sufficient, even though hydraulic presses of great power are used. After it comes out of the press, therefore, it is frequently boiled along with a little caustic soda in solution, just sufficient to combine with the residual oil, which will then be converted into a soap and can be skimmed off the surface. If too much alkali were added the spermaceti would in like manner be saponified, and a loss of material would ensue. It is afterwards washed with water, which removes all the soap that may have remained over from the skimming. The material being thus prepared, the candles are made in moulds with plaited wicks as above described.

The improvements in candle manufacture which have taken place of late years have caused the real sperm and wax candles to be greatly superseded. Every one is now familiar with those made of stearine or stearic acid. This substance is present not only in animal fats, but also in many of the vegetable oils; palm and cocoa-nut oils contain large quantities, and are now very extensively used in the preparation of stearine. The other principal ingredients are margaric and oleic acids, and glycerine. The former of these need not be altogether removed, but the oleic acid is much too liquid to suit the candle-maker, and the glycerine must be extracted, because it will not burn, and its presence would therefore diminish the illuminating power. Stearine, when thoroughly separated from these several substances, is a firm crystalline body, and makes a hard, clean, and good-looking candle, which gives a strong bright light.

Palm oil, when in its natural state, is very highly coloured, and it has therefore to be bleached. Most of the other substances are more or less tinged, and it is desirable to submit them also to a similar process. This is usually done after the ingredients which are not required have been removed from the crude oil.

There are several distinct processes for the separation of the stearic acid. Superheated steam will serve the purpose, and partially bleach it at the same time. The fatty matter is placed together with water in an iron chamber capable of bearing a pressure of about 2,000 pounds to the square inch, and is raised to a temperature of from 500° to 600° Fahrenheit. The glycerine then combines with the water, and on the contents

being drawn off into a tank, the stearic acid separates from the other substances.

The sulphuric acid process is, however, more commonly adopted, especially in the conversion of palm oil. It is first melted in large vats, and then passed into a leaden tank, where it is heated by steam to about 350° Fahrenheit. Strong sulphuric acid is then gradually added to the extent of about $\frac{1}{20}$ of the weight of the oil, the boiling being kept up all the time. After being left awhile to settle, the oil is transferred to the stills, where it is distilled over at a high temperature, the glycerine coming off first, and the ultimate product forming a tolerably firm substance on cooling, which without further preparation may be converted into candles. Those so made are called *composites:* the quality, however, can still be considerably improved. In order to make the best stearine candles, the fatty acid is shredded by a machine, and then spread evenly upon mats, which are piled one upon another, and then put under a hydraulic press: all the oleic acid is thus expelled. On taking the stearine out of the press, it is again melted with a weak aqueous solution of sulphuric acid, and after the liquor is drawn off, a very pure and hard stearine results on cooling.

A third plan of separating the glycerine is by converting the oil into a soap. For this purpose the alkalies used by soap-boilers are too expensive; caustic lime (hydrate of calcium), which is found to answer equally well, being used instead. The oil having been melted in vats by the introduction of steam, slaked lime, worked up with a sufficiency of water to make it about the consistency of cream, is gradually added, until the proportion of lime to the oil is about 15 per cent. by weight, the mixture being well stirred all the time. The vats are then shut down and kept at a high temperature for some hours, during which period the lime has combined with the fatty acid, forming a soap, while the glycerine has combined with the water. The mixture is then allowed to cool, the glycerine and water drawn off, and the residue well washed with cold water. The lime-soap contains oleic as well as stearic acid, but the next step is to separate the lime and leave the acids perfectly free. Sulphuric acid, having a great affinity for lime, is employed to effect this object. The soap is heated to something under the boiling-point with sulphuric acid and water, the weight of concentrated acid employed being about one-fourth of that of the soap to be decomposed. When the fat has separated and risen to the surface of the liquid, the sulphate of lime and water is drawn off, and the fatty acids are left to cool and solidify. The oleic acid is then usually removed by pressure, and the stearine is ready to be made into candles.

At first some difficulty was experienced in making them in moulds, on account of the great tendency of the stearine to crystallise. It was found that a small admixture of arsenic would prevent this, but its poisonous reputation prohibited its use. An addition of a little wax has the double advantage of preventing the crystallisation of the stearine, and of increasing the beauty of the candles; but a still simpler expedient has since been hit upon, all that is necessary being to regulate the temperature when the moulds are filled, so that the stearine shall only be just hot enough to allow it to run.

Within the last twenty years or so, a very important addition has been made to the sources of supply of the ingredient most important to the candle-maker. About that time many attempts were made to convert the peat bogs of Ireland into candles, but they were generally looked upon with incredulity. As a scientific experiment the attempt was quite legitimate, but as a commercial operation the candles produced were found to be vastly too dear. The material distilled from the peat was paraffin, but it could only be obtained in very small quantities and at great expense. The earth-oil from Rangoon, which is obtained in wells, was found to be rich in this ingredient, and it could be separated from it at a sufficiently cheap rate. It was also found to be present in considerable quantities in the Cannel coals, and the oil shales associated with them, and could be separated by distillation at a low red heat. The Bathgate shales near Edinburgh (otherwise called Boghead coal or Torbanehill mineral) being very rich in hydro-carbons, large works have been carried on there since the first discovery of their value, for the distillation of the paraffin and the mineral illuminating oils. It is now produced wherever cannel is found, the principal centre of the trade in England and Wales being in Flintshire, Cheshire, and Lancashire, coal of this description being raised at Mold and Wigan. The petroleums of the United States also yield this substance.

Paraffin is a pure hydro-carbon, containing nothing else than carbon and hydrogen, being precisely the same ingredients as in ordinary coal-gas, though in another form, gas being produced by distillation of the same substances at a much higher temperature. It is a colourless solid, not at all greasy to the touch, which melts readily at a low heat, and burns with a brilliant flame. Unlike the oils and fats spoken of above, it does not contain any glycerine. Ozokerit is also a mineral hydro-carbon, distilled from an oil shale obtained in Southern Russia; it has, however, a higher melting-point, which is an advantage in some respects. Pure paraffin melts at about 120° Fahrenheit, which is too low a point to be safe in a hot climate, and on which account it is generally mixed with stearine, the two together forming a very excellent candle.

There is one other article from which candles are frequently made, which demands consideration—wax. The material is not only different in character, but the manner of dealing with it is also quite distinct. Bees'-wax is a very familiar substance which scarcely needs description, but there is also Chinese wax, which is the exudation of an insect, and vegetable waxes, which are prepared from the berries and fruits of certain plants.

Bees'-wax is usually of a very decided yellow colour: it must in consequence be bleached. The ordinary bleaching agents cannot be applied, and therefore the wax has to pass through a process somewhat similar to what used to be adopted with textile fabrics in olden days. The wax is first melted by the agency of steam, to separate any extraneous matters, and then made into thin sheets, which are spread out in the open air and watered from time to time, until the greater portion of the colour is lost.

Wax candles are seldom made in moulds, on account of the difficulty of drawing them out after they have cooled. They are therefore usually made by another process, which is termed basting: the wicks are suspended to a frame over the caldron of melted wax, and instead of being dipped into the liquid, as in the case of tallow, the workman takes the wax up in a ladle, and pours it over the row of wicks in succession, until they have attained about one-third of their ultimate thickness. They are then removed from the frame, and rolled between marble slabs, in order to make them quite smooth and of uniform thickness. The candles are again suspended to the frame and basted as before, then rolled, and the ends trimmed with a knife, in order to make them all of the same length.

COLOUR.—X.

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CAUTIONS AS TO THE TRUE PRIMARY COLOURS AND CHROMATIC EQUIVALENTS—MODIFICATIONS OF COLOUR BY ILLUMINATION—DIFFUSED DAYLIGHT—LIGHT OF THE SKY AND CLOUDS—SUNLIGHT—A DOMINANT COLOURED LIGHT—ARTIFICIAL LIGHTS—TWO LIGHTS.

Before entering upon the consideration of the changes produced in coloured objects by the nature of the light which falls upon them, it is desirable to repeat a caution which we have given our readers more than once as to the value to be put upon our supposed set of three primary colours and their chromatic equivalents; for, in discussing the laws of harmonious assortments of colours, we have assumed the truth of both these doctrines, because we were dealing with pigments or dyes, and not with coloured lights (see Lessons VI., VII., and VIII.), while for pigments, the conclusions reached by Field, and generally adopted, so far as regards the relations and equivalents of colours, are of no small service. Field's conclusions were indeed obtained by imperfect methods, and relate, so far as they are true, only to colours produced by absorption; but it is, of course, precisely with this mode of producing colours that we are concerned when occupied with pigments. It will be well, however, to point out the special convenience of the primary triad of colours in general use by painters and ornamental colourists. Yellow, red, and blue have been selected, for artistic as well as practical reasons. With these colours, unmixed, but properly distributed over a painted surface, it is perfectly possible to get that kind of "neutralised bloom"

which all satisfactory colour-combinations should exhibit when viewed at a sufficient distance; just as a similar result may be secured by the mingling, through rotation or otherwise, of the same three colours. A second artistic or æsthetic reason for the selection of this triad lies in the variety thus secured. Yellow represents to the eye nearness, lightness, and brilliancy, and does not actually admit of anything like the intensity of the purest red. Red imparts an idea of warmth and richness, and is as far removed, in its several qualities and the sensation it awakens, from yellow as it is from blue. Blue gives us the element of coolness and retirement, and is less brilliant and more intense even than red. If we take the triad red, green, and blue, we have not the same range of effect at our disposal, red and green being removed from each by a far greater interval than that which separates green and blue. As to the practical uses of the two rival triads, there can be no hesitation in preferring the common one; for red and green pigments when mixed do indeed produce grey, and blue and yellow pigments, green; though were lights, not pigments, concerned, red and green would yield a yellow, and blue and yellow a white light.

We have already explained how the mixed nature of the rays reflected and absorbed by pigments causes this difference, this departure from the anticipated result; but the only thing we have to do under the circumstances is the adoption, for the special purpose, of a plan of mixing colours which can be successfully carried out in practice. The impressions which the retina of the eye receives, and which become translated by the brain into sensations of colour, are certainly produced in different ways. The mingled rays, for example, of red and bluish-green light produce a colour-sensation absolutely identical with that produced by the perfectly simple and pure yellow light of the spectrum; but it would be grossly incorrect to regard yellow as of necessity a compound colour for this reason, since we know it to be incapable of any kind of decomposition as it occurs in the solar spectrum and in most pigments. It is quite possible, also, to produce the colour-sensation of blue by the mingling on the retina of certain green and violet rays, yet this does not warrant us in regarding the solar blue rays as being otherwise than simple. But when we come to mix pigments on a palette we find that very different results occur, yet that in no case is a pure yellow, or red, or blue colour produced by any mingling of other colours. So our practical treatment of the colour-relation of pigments must differ from that of coloured lights.

We are also compelled to lay but little stress on the doctrine of chromatic equivalents. When pure coloured rays are experimented with, it is possible to learn the proportions in which they must be mingled to produce certain effects; but when the same problem is attempted to be solved in the case of pigments, the complexity of the subject baffles us, and our results are scarcely more than very rough approximations to the truth. Still, there is an obvious propriety in the more sparing use of luminous and brilliant colours, as yellow, as compared with those of great depth and intensity, such as blue; and if we find that mixtures in certain proportions of particular coloured pigments give colours approximating to certain standards, or produce neutral greys, we may consider such proportions as corresponding in some measure to the chromatic equivalents of the pigments in question. Thus it is found by experiment that two grains of nickel in the form of chloride yield a bluish-green solution, which is perfectly competent to neutralise the rose-pink colour of a solution of chloride of cobalt containing one grain of cobalt. In this instance, the nickel-green is related to the cobalt-pink in the proportion of 2 to 1. We trust that, without further dwelling upon these subjects of the primary colours and chromatic equivalents, we have said enough to show at once not only the use of our explanations in Lessons VIII. and IX. of colour-proportion, balance, and harmony, but also the reserve under which these explanations must be accepted. In passing on to the study of the modifying influences of different kinds of illumination upon the colours of objects, we would premise that the remarks just made must likewise be kept in view.

The quality and intensity of the light by which objects and their colours are discerned are liable to great variations, and produce corresponding changes in the colours reflected from the surfaces which they illuminate. Putting on one side, for the present, the variations produced by the nature of the substance or surface on which the light falls, we may consider the condition of a plane and uniformly-coloured surface as illuminated by

1. Diffused daylight, and sunlight;
2. A dominant coloured light;
3. Artificial lights, as candles, lamps, fire;
4. Two lights, of different quality or intensity.

§ 1. It is scarcely necessary to state that the light of day varies greatly in colour; the causes, however, of its variations may not be at once apparent. In reality, there is one chief active cause which originates its chromatic changes—*the air is not perfectly transparent*, it is more or less cloudy or troubled. Now even if the sun's luminous rays be purely white, they will suffer change by passing through a cloudy medium. The ease with which they pass will vary with the more or less complete approach to transparency of the atmosphere and its depth. Let us study in succession the blue light of the sky, the apparently white light of clouds, and the reddish light of direct sunshine.

How does the blueness of an unclouded sky originate? We may best explain it by means of an experimental illustration.

Upon a sheet of black glass or a surface of black japanned metal, place a drop of milk, diluted, if necessary—which will seldom be the case—with a drop of water. The milk is a cloudy medium; its minute particles reflect certain rays of very short wave-length—those towards the more refrangible or blue end of the spectrum; therefore, by reflected light, a drop of milk on a dark background appears blue. So, through a delicate skin, and a series of translucent but not transparent membranes, the light reflected where the dark background of a vein filled with venous blood exists, is blue. So, also, the translucent, but not absolutely transparent tissue of the iris of the eye often reflects a blue light, there being in this instance also a background of a black pigment, but no real blue colouring matter whatever. The blueness of the sky has a similar origin. Against the dark background of infinite space, a translucent medium is placed; this medium is the atmosphere. It is never transparent, countless millions of minute particles, chiefly of water, being suspended in it. When these particles are of a certain degree of minuteness and uniformity, they arrest the free passage of white light; this they do by a peculiar kind of "interference" (see Lesson II.). Each minute foreign particle of water gives rise to two reflections, one on each surface—one external, on the anterior surface; one internal, on the posterior. These reflected rays, passing from air into water, and from water into air, suffer different retardations, and, on emergence, cause the usual phenomenon of interference, namely, the production of colour. When the particles thus affecting the incident light are sufficiently minute and sufficiently numerous, the proportion of reflected green, blue, and violet rays, which together give the colour-sensation of blue, predominates greatly over the red, orange, and yellow rays, with their longer undulations. Thus, the reflected light of the open sky is blue; but let the thickness of the reflecting layer, or the number of the reflecting particles increase, and the blueness of the light decreases, for the solar light, which has been deprived by the kind of reflection just described of a great proportion of its more refrangible rays of short vibration, has become yellowish, or orange-tinted, and is no longer capable of furnishing an excess of blue rays. From this cause we see that while the light of the zenith is a distinct blue, it becomes gradually of a less pronounced tint towards the horizon, where it would be white if other conditions did not there produce other modifications of the reflected light. This exquisite gradation of tone in the sky is often missed by unobservant painters, who think that the same mixing of some blue pigment will do to represent the colour of the whole sky shown in their pictures.

Now if the reflected light of the blue sky owes its colour to a sort of sifting of the solar rays, it will be rightly concluded that the transmitted light, deprived by this process of its green, blue, and violet elements, will partake more or less distinctly of the colours of the residual rays of the solar spectrum. Such is the case. The light *transmitted through* a turbid medium shows a predominance of yellow, orange, or even red light. Direct sunlight partakes of this character, but it is generally more distinctly seen when the same object is illuminated by two lights, which can be compared and contrasted together. Yet there are cases in which the redness of sunlight is manifest enough. Not only

is bright sunshine spoken of by painters as warm in an artistic sense, because of its ruddiness, but the light of the sun, transmitted through a great thickness of a turbid atmosphere, often appears, as at sunset, of an intense red or crimson colour. The street lamps in a fog illustrate, by their gradually increasing redness as they become more distant, the same fact.

While, then, the light reflected from the sky is bluish, and that transmitted directly from the sun through an aqueous atmosphere reddish, the light of day is often white. The particles suspended in the air may be either too large or too small to produce the effect we have been discussing. Thus, through certain kinds of fog and mist the light of the sun reaches us, reduced in intensity it is true, but unchanged as to its quality of whiteness. So, also, the light reflected from dense masses of cloud is often nearly white, and at other times is grey, owing to a comparatively deficient illumination or to absorption. It will not be necessary to detail here the modifications of colour which objects undergo when illuminated by direct sunshine, or by the light reflected by the blue firmament or white clouds, as it may be readily learnt from the next succeeding paragraph, in which we treat of the effects of a dominant coloured light.

§ 2. When a landscape is viewed through a piece of neutral-tinted or grey glass, the rays of different colours belonging to different parts of the spectrum are intercepted to a nearly equal extent; when the glass itself is coloured, a different result ensues. Through a yellow glass, all objects acquire a yellowish tinge, not because the yellow glass actually adds any yellow rays to the light which it reflects, but because it cuts off the other coloured constituents of the light in different degrees, and so increases the proportion of yellow light conveyed to the eye. Objects which are originally yellow remain virtually unchanged, but relatively intensified; those which are red lose a small part of their red rays; those which are green assume a yellowish-green hue, since some of their green and blue rays are cut off; while blue objects acquire a greyish-green hue, owing to the suppression of many of their proper blue rays, and of the further sifting which the white light they reflect suffers. When, on the other hand, objects variously coloured are illuminated by a pure light of one colour, that is, monochromatic light, the results are different. All objects reflect naturally, if they have the opportunity, as in daylight they have, some white light; but when a pure coloured light is thrown upon objects usually distinctly coloured, they can either reflect no light at all, or only that which is incident upon them. But, in point of fact, when experimenting with coloured illumination of this kind, we have not to deal with pure red, or orange, or green lights. It will be most serviceable for the purposes of the practical application of our principles if we give some clue as to the modifications produced in the colours of objects by different qualities of light, in which certain rays severally preponderate, but, nevertheless, do not wholly constitute the light. Illuminated by a light in which yellow rays predominate, yellow objects become less distinctively yellow when put by the side of white objects, which then assume a yellow tint. Pale yellow gloves by the yellow light of a lamp are hardly to be distinguished from white gloves. Orange-coloured objects become, if anything, rather more yellowish in yellow light. Vermilion increases in brilliancy if the light be not very largely composed of yellow rays, but merely have them in preponderating number. Reddish and bluish violets become duller and redder, losing a part of their blue. Blue itself, when pale, becomes paler, and inclines towards a greenish blue; while dark and rich blues lose somewhat in intensity and purity. If, instead of white light tinged with yellow, we try the effects of yellow light accompanied by a small amount of white light, the effects are still more decided.

The following is in the main Chevreul's list of the modifications experienced by various coloured surfaces, when viewed in coloured light nearly pure, or in a dim diffused light with an intense coloured direct illumination:—

Yellow rays falling on	*white*	make it appear	*pale yellow.*
,, ,, ,,	*yellow*	,, ,,	*orange-yellow.*
,, ,, ,,	*orange*	,, ,,	*yellower.*
,, ,, ,,	*red*	,, ,,	*orange-brown.*
,, ,, ,,	*violet*	,, ,,	*brownish-violet.*
,, ,, ,,	*deep blue*	,, ,,	*greenish-slate.*
,, ,, ,,	*green*	,, ,,	*yellowish-green.*
,, ,, ,,	*black*	,, ,,	*blackish-olive.*

Red rays falling on	*white*	make it appear	*red.*
,, ,, ,,	*yellow*	,, ,,	*orange.*
,, ,, ,,	*orange*	,, ,,	*redder.*
,, ,, ,,	*red*	,, ,,	*redder.*
,, ,, ,,	*violet*	,, ,,	*reddish-violet.*
,, ,, ,,	*blue*	,, ,,	*violet.*
,, ,, ,,	*green*	,, ,,	*reddish-grey.*
,, ,, ,,	*black*	,, ,,	*rusty black.*

Blue rays falling on	*white*	make it appear	*blue.*
,, ,, ,,	*yellow*	,, ,,	*green.*
,, ,, ,,	*orange*	,, ,,	*plum-brown.*
,, ,, ,,	*red*	,, ,,	*violet.*
,, ,, ,,	*violet*	,, ,,	*reddish-violet.*
,, ,, ,,	*blue*	,, ,,	*bluer.*
,, ,, ,,	*green*	,, ,,	*bluish-green.*
,, ,, ,,	*black*	,, ,,	*bluish-black.*

Orange rays falling on	*white*	make it appear	*orange.*
,, ,, ,,	*yellow*	,, ,,	*orange-yellow.*
,, ,, ,,	*orange*	,, ,,	*reddish-orange.*
,, ,, ,,	*red*	,, ,,	*scarlet.*
,, ,, ,,	*violet*	,, ,,	*reddish-brown.*
,, ,, ,,	*blue*	,, ,,	*greyish-orange.*
,, ,, ,,	*green*	,, ,,	*greyish-green.*
,, ,, ,,	*black*	,, ,,	*brown.*

Violet rays falling on	*white*	make it appear	*violet.*
,, ,, ,,	*yellow*	,, ,,	*brown, rather reddish.*
,, ,, ,,	*orange*	,, ,,	*light greyish-red.*
,, ,, ,,	*red*	,, ,,	*reddish-violet.*
,, ,, ,,	*violet*	,, ,,	*deeper tone of violet.*
,, ,, ,,	*blue*	,, ,,	*bluish-violet.*
,, ,, ,,	*green*	,, ,,	*greyish-violet.*
,, ,, ,,	*black*	,, ,,	*slightly tinged with violet.*

Green rays falling on	*white*	make it appear	*green.*
,, ,, ,,	*yellow*	,, ,,	*yellowish-green.*
,, ,, ,,	*orange*	,, ,,	*greyish leaf-green.*
,, ,, ,,	*red*	,, ,,	*brown.*
,, ,, ,,	*violet*	,, ,,	*greenish-slate.*
,, ,, ,,	*blue*	,, ,,	*bluish-green.*
,, ,, ,,	*green*	,, ,,	*more intense a green.*
,, ,, ,,	*black*	,, ,,	*dark greenish-grey.*

The above results were originally obtained by Chevreul by exposing pieces of coloured cloth to diffused daylight, and illuminating half of each piece also by the light passing through glasses of the several colours named. The effects are consequently partly due to contrast, and are only true for the special conditions of the experiments performed. They, however, give us some notion of the various directions in which different coloured lights affect the colours of objects already moderately illuminated by diffused daylight. On this point see further the statements given under § 4 below.

§ 3. In considering the effects on coloured surfaces of yellow light we have in point of fact considered the effects of the light of gas, oil lamps, and candles upon them, for all the ordinary kinds of artificial light possess a superabundance of yellow rays. This preponderance is less marked in the case of paraffin oils and solid paraffin candles, the light of which, though far from white, is not so yellow as that emitted by burning stearine or tallow. By the side of objects illuminated by direct daylight, which is, we know, slightly reddish, the light of a candle, though really yellow, may appear orange, while direct sunlight itself may, by contrast, appear positively violet or blue. Now the general results of the yellow illumination of artificial lights upon coloured surfaces may be learnt by reference to the table given above, but it may be interesting to give in fuller detail one particular and familiar instance of the sort of effect thus produced. We allude to the strange effect of artificial light in altering the colour of certain violet colours, and of blues which possess a tinge of violet. Take as an example the precious stone known as the amethyst. A good specimen of this mineral presents by daylight almost the same tint as that of the flower of the violet, but at night, illuminated by lamp or candle-light, it loses much of its blueness, and acquires so distinct a reddish hue that it might be mistaken for a red garnet or carbuncle. This change is due to the deficiency of blue in the artificial light, while ordinarily the red of these stones is annulled partially by the greenish-blue element of daylight. A similar instance of a change in colour has been observed with some sapphires. The *saphir merveilleux* in the Hope Collection, South Kensington Museum, presents a clear blue tint by

daylight, but by candlelight it appears violet. Certain flowers show a still more curious property. The flowers of the viper's bugloss (*Echium vulgare*) and of the marsh forget-me-not (*Myosotis palustris*) are rose-coloured in the bud and when they begin to open, but afterwards, on fully expanding, become blue as viewed by daylight. By artificial light, however, the change appears not to have taken place, at all events, to any great extent, since a spray of one of these plants thus seen by candlelight shows its buds red or rose-coloured indeed, but its fully-opened flowers are not blue, but only pink or a pale purplish-red. The difference between red and a blue verging on purple is thus partially annulled. So, also, as regards blues and greens; the ordinary green and blue pigments, with very few exceptions (*e.g.* aniline green), are hard to distinguish by candlelight. Those blues which verge on green do so, of course, by the special absorptive power which they possess for the yellow, orange, and red rays, and their power of reflecting the green, the blue, and the violet. Now, as candlelight is deficient in blue and violet, the green of these blue pigments then comes out in unusual force. Such serious changes are experienced by some blues under artificial illumination that it is often advisable to substitute green for blue in colour-combinations which are to be viewed at night by gas or candles. The triad *red—yellow—green* becomes under such circumstances superior in effect to the triads *red—yellow—ultramarine blue*, and *crimson—yellow—Prussian blue*. So yellow, to be seen well and effectively by candlelight, must incline towards orange or a golden hue; but white, on the other hand, if it be meant to appear white, must by no means be tinted with a shade of blue, with the intention of purifying it, and neutralising the yellowness of the illumination on the material. This plan in daylight is effective, but by candlelight dulls the brilliancy of the white, by the absorption of certain rays of light which it causes.

§ 4. A double illumination, where the lights are of different quality, produces some striking effects of contrast. Such effects are often seized upon and reproduced, within varying degrees of fidelity, by those artists who delight in painting forges, candlelight scenes, and conflagrations. In order to study the conditions and effects of double illuminations, the following experiment may be made. Place a sheet of pure white paper in such a position that it may be illuminated at the same time by diffused daylight and by the light of a candle. Now arrange an opaque rod vertically, so that it may throw two shadows upon the paper. The shadow thrown by the daylight will be tinged with yellow, while that produced by the candle will be bluish; the doubly illuminated surface being itself white. Now we have before pointed out (see § 3 above) that candlelight possesses a superabundance of yellow rays, and is therefore more yellow than the light of day. In consequence of this, the shadow of the rod, as cast by the light of the candle, and illuminated therefore only by candlelight, appears yellow. Conversely, as the light of day is bluish compared with that of a candle, the shadow of the rod as cast by the light of the day, and illuminated therefore only by daylight, appears blue. Of course the contrast between the colours of the two shadows is enhanced in accordance with the laws of contrast, as previously pointed out in Lessons V. and VI. Similar results are met with every day in the case of objects illuminated at the same time by a natural and by an artificial light. The lamps of a church may illuminate some parts of the furniture and floor with a yellowish light, overpowered and contrasted in other parts by the apparently purplish light of day. A remarkable effect of this kind is seen when strong sunlight illuminates a room through a window partly screened by a yellow or buff-coloured blind. Here the contrast and relativeness of the colours seen become very distinct. The light transmitted through the material in common use for blinds of this sort is of an orange tint, and it will be seen that the direct rays, escaping filtration through this medium, are of a beautiful reddish-purple colour. More complicated effects of the same nature may be observed in the case of stained glass windows. The simplest case of this kind that we can recall just now is, perhaps, that of windows glazed with a pale greenish glass, but bordered with strips of white glass, when the latter will appear pinkish under some conditions of natural illumination. The effect here is, of course, not wholly due to the proper or intrinsic colour of the daylight, but to the effect of complementary contrast between the white glass admitting the natural rays almost unaltered, and the greenish glass which very materially affects them. But the most magnificent and beautiful effects of this order are to be watched in the phenomena of sunrise and sunset. When a range of distant mountains is seen against the sky about the time of sunset, the effects produced may be readily explained. If the sun be sinking behind the mountains, the shadows which it casts will be illuminated moderately by scattered and reflected lights of a blue or bluish-violet hue, produced by the minute particles disseminated throughout the atmosphere. These hues will be to a certain extent real and objective, derived from the peculiarity of the light itself, and the colours of the objects and surfaces which it discloses. If these objects be grey, as many rocks, or white, as snow, then the blue or violet hue will be distinct, but it may be modified by the local colouring of the rocks or trees of the landscape. Still further, it will be changed or intensified by subjective contrast with the colour of the sky, for the light from the sky will reach an observer modified by its passage through a turbid medium, the air, and it will thus be yellow, orange, or red, according to the amount of blue, or more refrangible rays, which it cuts off. So the sky near the western horizon will often be of an apple-green colour, with clouds of greyish-purple edged with scarlet, all these variations being produced by the decomposition of solar light by its passage through a medium which is not perfectly transparent, and the consequent conveyance to the eye, in varying proportions, of lights of higher refrangibility which have been reflected, and of lights of lower refrangibility, which, escaping complete absorption, have been transmitted.

Hitherto we have regarded the colours of objects as they are modified by the quality of the light which falls upon them. We have to study in the next place the influence of the structure, surface, and material of the objects themselves upon their apparent colours.

MINING AND QUARRYING.—III.

By George Gladstone, F.C.S.

COAL.

DIFFERENT KINDS OF COAL—ANALYSIS—HEATING POWER—ILLUMINATING POWER—BORING FOR COAL.

Although by far the greater part of all coals consists of carbon, the various kinds of coal possess very different qualities; and it is necessary to keep these distinctions in mind in order to select the most suitable description for any given purpose.

At one end of the series is the anthracite or non-bituminous coal, and at the other extreme the cannel, which is used for making gas and illuminating oils. Between these are several varieties more or less bituminous.

Anthracite is principally met with in the western portion of the South Wales coal-field, and in Ireland; but it occurs to a limited extent in other districts. It is very hard and heavy, and is often called "stone coal." The specific gravity is about 1·37, being about the heaviest coal known, excepting impure specimens containing a large proportion of mineral matter. The consumption is not very large, as it will not burn in open grates. It is used in some factories because it gives off little or no smoke; but it requires so strong a draught, and only burns at such a high temperature, that it is very destructive of the furnace-bars. In the Swansea valley it has been used for iron-smelting, and on account of its general freedom from sulphur is very suitable for the purpose; but even in the blast furnaces it does not burn readily. The Pembrokeshire anthracite is highly prized by maltsters, to whom a coal perfectly free from smoke and sulphur is most important.

The semi-bituminous or steam coals come next in order. They do not light up readily, but they contain a large percentage of carbon, and give out a great deal of heat in proportion to their bulk. The best South Wales descriptions have also the advantage of making but little smoke; but they are more tender, and will not bear shipment to hot climates so well as the Newcastle steam coal. The hard splint coal of Scotland may be classed with these. In many places the latter is employed by iron-smelters without being first converted into coke.

The free burning or bituminous coals are the most familiarly known. They burn brightly in an open stove, and are approved

as the best household coals. They give out a yellow flame, and a considerable amount of smoke, but do not produce so much heat as the preceding. They often cake together as they burn, and yield an excellent coke.

The last in the series are the cannel coals. They occur principally in the Scotch, Lancashire, and Flintshire coal-fields. Unlike other descriptions they break with a conchoidal fracture, and more resemble an opaque blackish resin than a true coal. When set fire to they flare up with a whitish flame, and have been used as a substitute for candles—hence the name. The best descriptions of cannel are the lightest coals known in this country, the specific gravity of the Boghead being as low as 1·15. They are used in gas-works, being very rich in hydro-carbons. By distilling at a lower temperature, they yield paraffin, benzole, and illuminating oils, as well as a variety of other useful products.

It may generally be put down that if heat be the object desired, the coal most suitable will be that which is richest in carbon; but if illuminating power be required there must be a certain proportion of hydrogen in combination with the carbon. These are not the only considerations, however. No coal consists simply of these two substances. There is always more or less mineral matter, which is generally useless, and often deleterious. Sulphur is a very common ingredient. On examining minutely almost any coal, small specks or threads of a bright yellowish mineral may be detected, called *brasses* by the miners. They are pyrites, or sulphuret of iron. The worst pieces are picked out when the coal is brought to the pit's mouth, but sometimes they escape notice. In an open fire they split with considerable violence, and are thrown out, or produce the disagreeable sensation of burning sulphur. In a close furnace they exercise an injurious effect on the ironwork and furnace-bars. It is still more objectionable in gas-works and blast-furnaces. In well-regulated establishments, therefore, it is customary to analyse the coals, not merely for the sake of calculating their heating or illuminating power, but also to ascertain precisely the amount of sulphur they may contain. For use on ship-board economy of space has also to be considered, as well as heating power; and a very extensive series of investigations has been made for the Admiralty, in order to determine which coals are best suited for Her Majesty's steam navy.

The following analyses, taken from the Admiralty lists, will serve as specimens of good steam coals, an anthracite being put at the bottom of the table by way of comparison:—

Name of Coal.	Specific Gravity.	Carbon per Cent.	Hydrogen per Cent.	Nitrogen per Cent.	Oxygen per Cent.	Sulphur per Cent.	Ash per Cent.
Ebbw Vale	1·27	89·78	5·15	2·16	0·39	1·02	1·50
Duffryn	1·33	88·26	4·66	1·45	0·60	1·77	3·26
Nixon's Merthyr	1·31	90·27	4·12	0·63	2·53	1·20	1·25
Graigola	1·30	84·87	3·84	0·41	7·19	0·45	3·24
Llangennech	1·31	85·46	4·20	1·07	2·44	0·29	6·54
Average of South Welsh	1·30	87·73	4·39	1·14	2·63	0·94	3·16
Haswell	1·28	83·47	6·68	1·42	8·17	0·06	0·20
West Hartley	1·26	81·85	5·29	1·69	7·53	1·13	2·51
Buddle's West Hartley	1·23	80·75	5·04	1·46	7·86	1·04	3·85
Hasting's Hartley	1·25	82·24	5·42	1·61	6·44	1·35	2·94
Carr's Hartley	1·25	79·83	5·11	1·17	7·86	0·82	5·21
Average of Newcastle	1·25	81·63	5·51	1·47	7·57	0·88	2·94
Ince Hall, Pemberton } Lancashire.	1·27	77·01	3·93	1·40	5·52	1·05	1·09
Rushy Park } Lancashire.	1·28	77·76	5·23	1·32	8·99	1·01	5·69
Elsecar } Derbyshire	1·29	81·93	4·85	1·27	8·58	0·91	2·46
Staveley } Derbyshire	1·27	79·85	4·84	1·23	10·96	0·72	2·40
Elgin } Scotch	1·20	76·09	5·22	1·41	5·05	1·53	10·70
Kilmarnock } Scotch	1·24	[illegible]·82	5·82	0·94	11·31	0·86	1·25
Bagillt, North Wales	1·27	88·48	5·62	2·02	0·86	1·36	1·62
Welsh Anthracite	1·37	91·44	3·46	0·21	2·58	0·79	1·52

Of the South Wales coal it will be remarked that their specific gravity is high, that the first three are superior to the other two in quantity of carbon; but that while the two latter are deficient in this respect, and leave too much ash, they have the advantage in freedom from sulphur. Of the Newcastle descriptions the Haswell gives the best results. Of the miscellaneous list the Elgin appears the worst, having a low specific gravity, and an unusual quantity of ash, which indicates a low heating power. The Rushy Park, too, has an excess of incombustible matter.

An analysis, however, is not sufficient of itself to settle the relative merits of different coals; and accordingly an experimental boiler was set up in which they were practically tested. The following are the average results arrived at—A being the number of pounds of water evaporated by one pound of fuel; B the number of pounds of water evaporated per hour; C the number of cubic feet occupied by a ton of coal; D the per-centage of large coals:—

Coal.	A.	B.	C.	D.
South Welsh	9·05	448·2	42·71	60·9
Newcastle	8·37	411·1	45·30	67·5
Lancashire	7·94	447·6	45·15	73·5
Scotch	7·70	431·4	49·99	73·4
Derbyshire	7·58	432·7	47·45	80·9

From these figures it appears that the South Wales coal is best in respect of evaporating power, but worst in point of durability. The last column is of particular significance when coals have to be sent out to distant naval or mail packet stations, as they frequently lie there for many months exposed to the weather, during which time a tender coal will crumble away so much as to be almost worthless; the result being that it either chokes up the furnaces or passes through the fire-bars before it is entirely consumed.

In dealing with the cannel coals, the principal points to be considered by the analysts are, the amount of volatile matter, and the freedom from sulphur. The following are specimens of some of the best from the Scotch coal-fields:—

Cannel Coal.	Volatile Matter per Cent.	Sulphur per Cent.
Boghead (brown)	71·06	0·24
Do. (black)	62·70	0·35
Torbanehill	67·11	0·32
Lesmahagow (Auchinheath)	56·23	0·55
Do. (Southfield)	49·34	1·35

In actual product of illuminating gas, some of the principal English and Scotch coals may be enumerated:—

Scotch.	Boghead	15,000 cubic feet of gas per ton.
Scotch.	Lesmahagow	13,500 ,,
Scotch.	Capeldrae	14,400 ,,
Scotch.	Wemyss	14,300 ,,
Lancashire.	Wigan	11,400 ,,
Newcastle.	Pelton	11,500 ,,
Newcastle.	Pelaw	11,500 ,,
Newcastle.	Pelaw Main	12,400 ,,
Newcastle.	Gosforth	10,000 ,,
Newcastle.	Dean's Primrose	11,100 ,,

We must now turn to the various operations connected with coal-mining itself—an industry which, for many obvious reasons, when it is remembered that at present this country is the chief coal-producing country in the world, must always be attended with peculiar interest to English readers. To the coal that lies in such vast masses under the surface of our soil must be attributed the chief share in raising our importance as a nation to its present height, for without it we could never have attained the eminence we now possess as a manufacturing country, or have been able to utilise other valuable sources from which much of our wealth is derived.

The first step is to explore the ground, in order to ascertain what seams there are, their course, thickness, and whether disturbed by faults (or troubles, as they are often called by the miners). Upon a careful determination of these points much of the future success of the colliery depends. In hilly districts, or where the strata are very highly inclined, the seams may be sometimes traced at the surface, and a very slight excavation will be sufficient to enable one to calculate the angle of dip of the beds. So far the investigation is easy enough, but it does not follow that it continues uninterruptedly, or in the same plane through the mountain. In the more ordinary instances

the coal seams are some distance below the surface, and they can only be mapped out by an elaborate system of borings.

Fig. 6 is an imaginary section of a coal property. The strata have a general dip from east to west of about 1 in 5; but the position of the coal seams, represented by the letters A, B, C, D, has yet to be ascertained, in order to determine whether they are worth working, and which would be the best point for sinking the shaft. A trial by boring might be commenced at No. 1, and at a depth of say forty fathoms the double seam A would be pierced through. Calculating the dip at 1 in 5, this seam, then, should crop out at the surface at about 200 fathoms east of No. 1. In order to make pretty sure of cutting the same seam again, allowances must be made for any difference in the level, and for broken ground at the surface, so that the next bore would be made at a somewhat less distance, say at No. 2. This one realises the expectation of the borer: it cuts the double seam A near the surface, and at about sixty fathoms it comes upon another seam, B. The ground is thus proved to be regular between these two borings, and B may be inferred to pass under No. 1, at a depth which can be easily calculated. A third boring would then be commenced at 3, with the expectation of cutting B near the surface; but here the workman is disappointed, and he bores down for about sixty fathoms, when he comes upon a thick coal seam, C, evidently a different one from either of the others hitherto discovered. He knows by this that there is a dislocation somewhere between 2 and 3. Again he tries at 4. At first he passes through rock of the same character as that overlying C, but suddenly it changes, and he finds himself again in unknown ground; but boring on he comes to another double seam, D, apparently not the same as A, the size of it and the nature of the accompanying rock both being different. He tries again at 5, and cuts the seam D at a lower level than he ought by calculation, while, it will be observed, he has missed C altogether. These five borings, then, will not be sufficient to enable the borer to make a complete section of the strata, but he has, nevertheless, ascertained the principal features. Having struck D twice, he can calculate where C will be found between 4 and 5. He has proved that in the neighbourhood of 4 there is a downthrow of about twenty-five fathoms, though he does not know the precise angle of the fault. In like manner he knows that there is another somewhere between 2 and 3, but he has not ascertained its exact position or extent. Of the position of the seams C and D, to the west of this fault, he knows nothing at present. Practically the explorer usually gets a good deal of information from a study of the sections displayed in neighbouring collieries; and thus he may be able to complete the section, having by his own borings established so many points.

In the preceding instance, the plane of the stratification or line of dip is supposed to have been already known. But that has often to be ascertained, which is done by making the third bore at such a point as will form with the two others an equilateral triangle (see Fig. 7). Suppose the coal seam at A is five fathoms lower than at B, and at C is only four fathoms lower than at B, the borings being at 100 fathoms' distance from one another; extend the line B C to D. Then as the difference between the respective depths of B and C (four fathoms) is to the distance between them (100 fathoms), so is the difference between the depths of B and A (five fathoms) to x, a point on the line B C D. As $4 : 100 :: 5 : x$ or 125 fathoms from B. At x, then, the depth will be the same as at A; a line joining these two will be upon the level or plane of stratification, and the true dip will be at right angles.

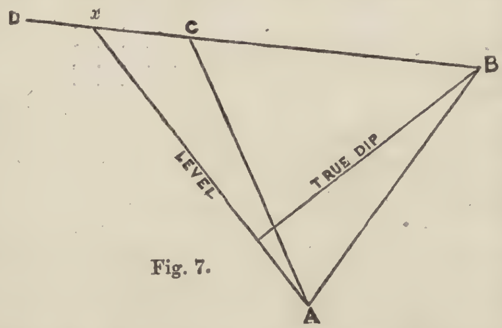


Fig. 7.

It is the object of the borer so to arrange his work as to gain as much information as possible without going to a great depth, as the cost per fathom increases rapidly as you go deeper. One boring of eighty fathoms is more costly than three of forty fathoms each.

The tools employed, and mode of working, must now be described. The ordinary cutting instrument is a chisel of the best hardened steel fixed to an iron rod which can be lengthened indefinitely by screwing on other rods as required, each joint being provided with a male screw at one end and a female at the other, the top joint of all having a head to it through which a cross-bar is passed. The workmen take the cross-bar and go round and round, by which means the chisel gradually cuts away the stone, and the rod sinks deeper and deeper in the bore-hole. At first the work is light, but with the addition of fresh joints the rod becomes very heavy, and the pressure has to be eased. For this purpose a pulley is fixed above the head, and a rope, attached to a windlass, is passed over the pulley and fastened to a ring in the head of the rod. This machinery also comes into requisition in drawing the rods, which has to be done periodically, in order to ascertain the nature of the rock which the bore is passing through. The sludger is partly hollow, and has a valve in the lower part, opening inwards, which receives the mud produced by the grinding of the chisel, and is thus brought to the surface. The samples thus periodically brought up are carefully preserved in bottles, and their depth recorded, experienced borers being able to tell from the appearance of the mud the character of the different strata they pass through. When approaching a coal-seam, this has to be constantly attended to, as it is only thus he can measure the thickness of a seam when he comes to one; and without determining that point accurately his explorations would be of little value. There are chisels and other tools of different shapes which are found necessary at times; and sometimes, especially in deep borings, the rod is liable to get bent or broken, in which case other implements have to be used to extract it, occasionally a matter of no little difficulty. The rods are usually made of the best tough Swedish iron, about an inch and a quarter in diameter, the edge of the cutting chisel being about three inches wide. The rods are made of uniform length, so that they serve as a measure of the depth of the boring.

The coal-field being thus tested, the next article will proceed to describe the plan to be adopted in opening out the mine.

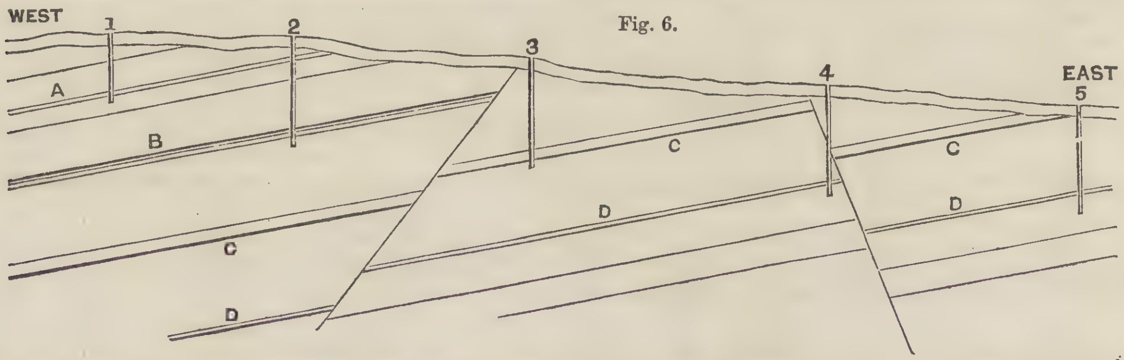


Fig. 6.

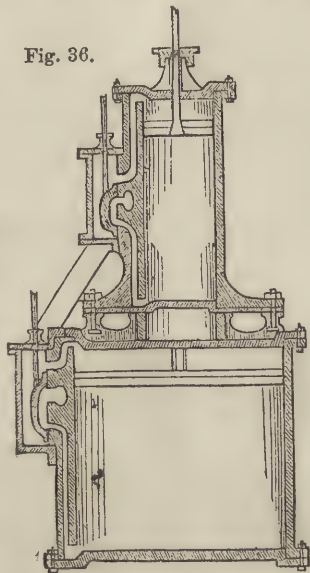
THE STEAM-ENGINE.—IX.

By J. M. Wigner, B.A.

SINGLE-ACTING ENGINE—NON-CONDENSING ENGINE—DOUBLE-CYLINDER ENGINE—HORIZONTAL ENGINES.

The engine which we have described and figured in the last article, though not of the form most commonly employed, may be taken as the best type that could be chosen to exhibit the general principles on which all engines act; and for this reason it was described first. In the present paper we propose to consider the principal modifications of this type which are introduced into stationary land engines. Marine engines and locomotives will be noticed in a succeeding paper.

Fig. 36.



In this engine the piston, it will be observed, is moved in both directions by the force of the steam, which is admitted alternately to either end of the cylinder. It is therefore known as a double-acting engine, and nearly all engines are thus made.

In a few cases, however, the steam is only made to force the piston in one direction, and a counterpoise is affixed to the other end of the beam so as to draw the piston back again to the end of the cylinder from which it originally started. This was the kind of engine first introduced, but it has now quite gone out of use, except in a few special cases in which nearly all the work has to be performed while the piston is moving through the cylinder in one direction.

Many large pumping engines are of this class, and these are often required for raising water to supply towns, or in mining districts to keep the mines dry by removing the immense quantities of water which find their way into them from land springs.

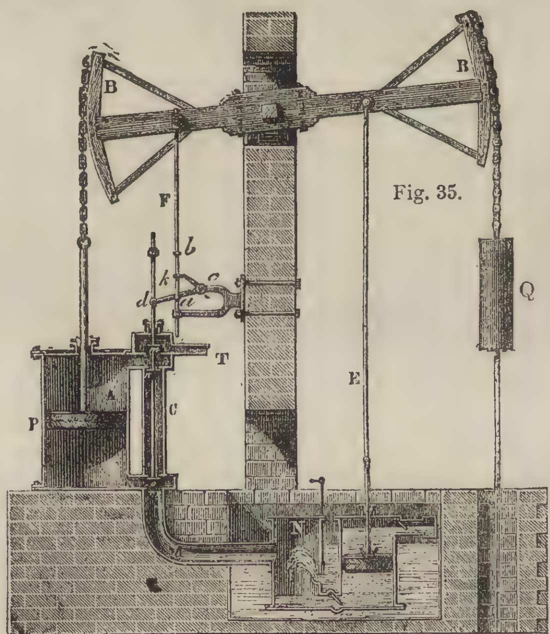


Fig. 35.

In the latter case a series of cisterns are placed in the shaft of the mine above one another at intervals of about thirty feet, and a pump forces the water from each of these into the one above it. These pumps are usually made with heavy solid plungers which are raised by the engine, and then fall by their own weight, thus forcing up the water. In this way all the strain on the engine is during the interval that the pump-rod, to which all the plungers are attached, is ascending: a single-acting engine, therefore, will answer every purpose.

Fig. 35 gives us a sectional view of an old form of engine of this class, and shows its action. The beam-ends here are arched, and the rods connected by chains, this being the usual plan before the invention of Watt's "parallel motion." After the description of the double-acting engine in our last paper, the way in which this is driven by the steam will very easily be understood without any lengthened description. T represents the pipe by which the steam enters from the boiler, and when the valves are in the position shown in the figure it acts directly on the upper side of the piston, forcing it down, and thus raising the pump-rods and the counterpoise Q, which are attached to the other end of the beam B B.

All the valves are tappets, and are attached to the valve-rod *d*, so that they all move simultaneously. The rod *d* is jointed near its centre to a bent lever *d c k*, hinged to a support at *c*; the end *k* is made into a ring through which the tappet-rod F passes, and the tappets *b* and *a* on this move the lever at the right moments. There are three valves on the valve-rod; the upper one, *m*, regulates the entry of the steam to the upper end of the cylinder; the lower one, *o*, governs the communication of the lower end with the condenser, N; while the middle valve, *n*, serves to establish a communication between the two ends of the cylinder, and is known as the equilibrium-valve. In the position shown *m* is open, so that the steam is pressing the piston down; *o* is also open, and through it the lower end of the cylinder communicates freely with the condenser. When the down stroke is nearly completed the valve-rod is lowered by means of the stud *b*. The result of this is that *m* and *o* are both closed, so that the cylinder is now cut off from both boiler and condenser. The equilibrium-valve *n* is, however, opened, and by means of this a free passage is made for the steam to pass from the upper end of the cylinder to the lower. By this all steam-pressure is removed from the piston, and it is left perfectly free; the weight of the rods and counterpoise, therefore, raise it again to the top of the cylinder. In doing this the valve-rod *d* is raised by the lower tappet, and thus the steam is again allowed to act on the piston, and causes it to make another descent, and in this way the motion is sustained. The weight of Q is, of course, made to bear a due proportion to that of the piston and rods; in some cases the rods are quite heavy enough without any counterpoise at all, and it is then dispensed with. No fly-wheel is necessary in this case; it would, in fact, be a hindrance rather than a help, since the action of the engine is not uniform, nor is it required to be so.

Though single-acting engines are frequently used for pumping purposes, we must not imagine that none but these are so employed. Many of the better pumps are made double acting, so that the water is raised during each stroke of the plunger, and with these a double-acting engine is, of course, required. A fly-wheel is, however, unnecessary, since there is no special need for any uniformity of motion. Some of the largest engines in the world are those used in Cornwall for drainage purposes in connection with the extensive mining operations carried on in that locality. In these engines, as a rule, economy of fuel is carried to the greatest extent possible. This partly arises from the plan already alluded to of registering and publishing statements of the work accomplished by each engine as compared with the fuel employed, and partly from the fact that they are worked with steam at a very high pressure, and cut off at an early part of the stroke. This, of course, produces some irregularity in the movement, but with a pumping engine this is by no means material.

Both the engines we have described are condensing, or, as they are frequently called, low-pressure engines. The latter term, however, is not strictly accurate, since condensing engines are very frequently worked with steam at a high pressure. The strict division is into condensing and non-condensing engines, but the other terms are frequently used, and if we bear in mind that they are used almost synonymously no inconvenience will arise.

Considerable saving is, as we have seen, effected by the use of

a condenser, since nearly the full pressure of the steam is transmitted to the working beam, and thus to the machinery. The advantage produced, however, is not all clear gain, since the condenser with its attendant pumps occupies much space, and thus adds considerably to the prime cost of the engine. Besides this, too, a certain portion of the power of the engine is consumed in imparting motion to the cold water and air pumps.

In many cases the space available for an engine is but limited, and then the additional room required for the condenser and its arrangements is a serious drawback. Hence we find that very often this part of the engine is entirely omitted, and the steam, instead of passing from the exhaust into the condenser, is allowed to escape directly into the air. The first consequence of this is clearly a considerable loss of power, for the exhaust side of the piston is now exposed to the air, which thus is allowed to exert its full force on the side of the piston opposite to that on which the steam is pressing, and this force has to be overcome before the piston can be moved. The working force, therefore, is only the excess of the steam-pressure over that of the air—that is, a deduction of nearly 15 pounds per square inch has to be made from the pressure of the steam when calculating the actual power produced.

It is clear from this that in non-condensing engines steam must be employed at a higher pressure than is required in one that has a condenser. The least pressure that will suffice is about 20 or 22 pounds, and nearly always it is considerably greater than this, for as the pressure increases the proportional loss caused by the opposition of the air becomes less. In most instances, however, the smaller bulk and greater convenience of a non-condensing engine render it the most advantageous form. The steam, when it escapes from the exhaust, is, however, often utilised in some way so as to prevent the total loss of the heat which is stored up in it. Sometimes it is employed to warm the feed-water, or to heat a drying closet, or in many other ways.

Some large engines are now constructed with two cylinders, one of which is worked at a high, and the other at a low pressure. In these cases the steam first enters the high-pressure cylinder, and having accomplished its work there, passes through the exhaust to the other cylinder. This latter is fitted with a condenser, and thus the steam as it leaves the first has quite sufficient force to work the piston in the second. Fig. 36 represents one form which is sometimes given to an engine of this construction. The high-pressure cylinder here is firmly secured to the cover of the other, and the steam passes from the exhaust to the valve-casing of the lower cylinder by a pipe seen behind it. Sometimes both pistons are fixed on the same rod, a well-made stuffing-box being placed between the cylinders. This is, however, very awkward to get at when placed thus, and to obviate the difficulty, two piston-rods are often fixed to the lower piston. One of these passes on each side of the upper cylinder, which is of smaller diameter than the lower, and above it there is a cross-head to which all three piston-rods are fixed, and this imparts motion to the beam.

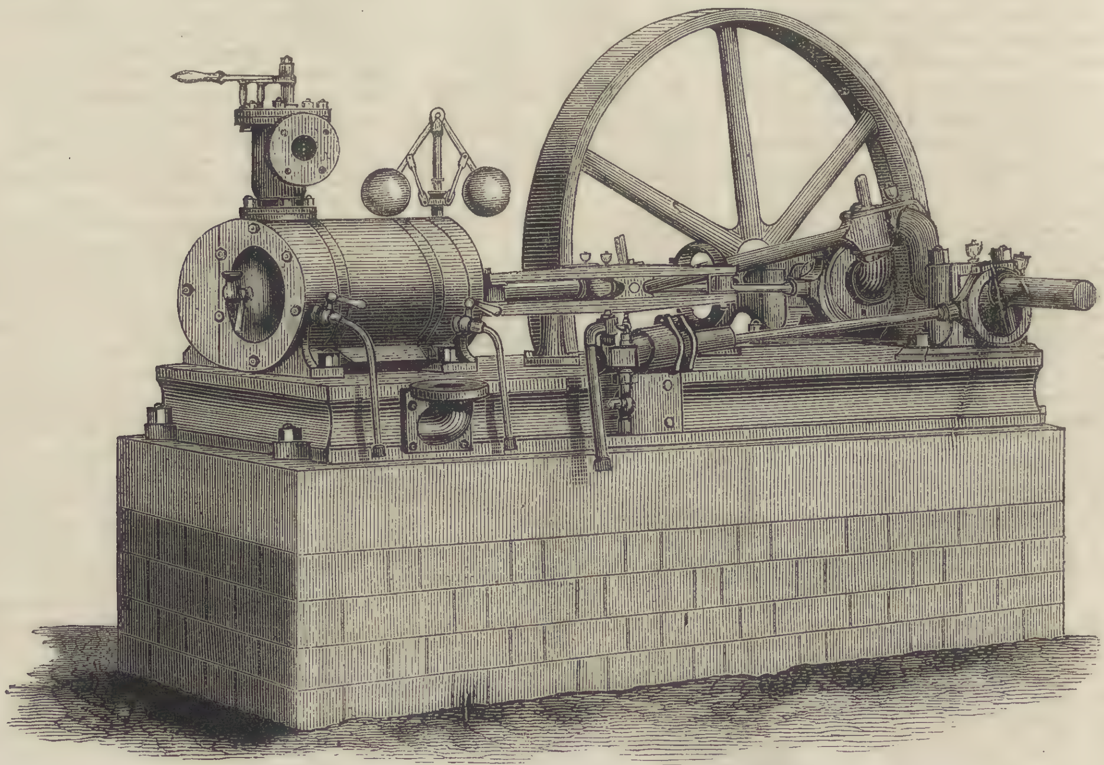


Fig. 37.—STEAM-ENGINE WITH HORIZONTAL CYLINDER.

The rods which work the slide-valves are likewise joined to a small cross-head placed above them, and thus both are worked simultaneously. In the engine here shown, two precisely similar valves are used, but in other forms the arrangements are so modified that a single compound valve governs the supply of the steam to both cylinders.

There is some diversity of opinion respecting the action of double-cylinder engines as compared with those which have but one. At the New River Waterworks near London, two engines were erected some time ago of the same power, but one fitted with two cylinders, and the other with only one. The performances of these have been carefully noted, and it is found that with a given expenditure of fuel, as nearly as possible the same amount of work is performed by each, so that it seems difficult to say which of these classes of engine is the more economical and satisfactory in its action.

The engines we have figured and described hitherto have all had a working beam, and this form is very frequently given to large stationary engines. It will, however, at once be seen that in many cases an engine of this construction would be quite inadmissible, since a large amount of room is occupied by it, and

it cannot be moved at all from place to place. Besides this, in a small engine, the force expended in moving the beam would be a serious waste; hence in most engines it is altogether dispensed with. In those which do not condense the steam, a cold-water pump is manifestly unnecessary, and we have, therefore, only to make some arrangement by which the piston shall impart motion directly to the fly-wheel without the intervention of the beam, and also to provide for the boiler being duly fed with water.

Occasionally the fly-wheel is supported directly over the cylinder, a cross-head is then attached to the piston-rod, and made to move between guides so as to keep it in a perfectly vertical position, and a connecting-rod joins this to the crank. This is known as a "crank-overhead engine," but is not very generally used. Its great advantage is the little ground-space it occupies.

The most usual plan is to have the cylinder horizontal (Fig. 37), and fixed to one end of the bed-plate of the engine, while the axis of the fly-wheel is at the other end. The fly-wheel is then by the side of the bed-plate, and a slit is frequently cut in the floor to receive its lower portion. Here, as in the engine just described, a cross-head is fixed to the piston-rod, and slides between parallel slots in guide-plates secured to the bed, and thus lateral strain on the piston-rod is avoided. The connecting-rod is jointed with a pin to the cross-head, and by this and the crank the fly-wheel is put in motion. The eccentric is fixed, as usual, on the axis of the fly-wheel, and, by means of a rod, moves the slide-valve, and thus regulates the supply of the steam.

The governor balls are placed on a special support, and are driven by an endless band and a spur-wheel. The whole engine is, as will be seen from the figure, very compact. The smaller sizes are usually made with all the parts firmly fixed to one solid bed, and all that is requisite is firmly to secure this to the concrete or masonry on which it rests. Sometimes a feed-pump, driven by an eccentric or crank, is fixed to the engine; but in many cases, especially where a number of small engines are driven by steam derived from one boiler, some other plan is adopted, and not unfrequently a small steam-pump is provided specially to supply the requirements of the boiler.

PRACTICAL PERSPECTIVE.—VIII.

FIGS. 39, 40, 41.—The object of this study is a block of four stone steps, with a wall at each end carried up to the height of the upper step.

Of this object, Fig. 39 is the plan and Fig. 40 the end elevation—the wall in this being supposed to be transparent, so that the exact position of the steps beyond it may be seen.

Having found the vanishing-points and measuring-points, according to the angles at which the plan is placed, it is advisable, in the first place, to put into perspective the entire block, out of which the whole object is, as it were, hewn.

The student who has followed the course of lessons on Projection will have no difficulty in understanding that the end elevation A C *d* D would stand on the line A C of the plan, the line A D standing upright in A. Therefore at A′ in Fig. 41 draw the perpendicular A′ D, and from A′ and D draw lines to vanishing-point VP1

From A′ set off A′ C′ equal to A C in Figs. 39 and 40, and from C′ draw a line to MP1, which, cutting A′VP1 in *c*, will give the place for the distant perpendicular *c d*, and this will complete the general form of the end elevation.

On the perpendicular A′ D mark off the heights of the steps—viz., 1, 2, 3—and draw lines from these points to VP1.

From A′ set off on the picture-line the lengths 1, 2, 3, representing the widths of the treads of the steps, and from these points draw lines to MP1, cutting A′ *c* in 1′, 2′, 3′.

At 1′, 2′, and 3′ erect perpendiculars, meeting the lines drawn to VP1 from 1, 2, 3 on A′D, and these intersecting will give the inner and outer angles of the steps, F, G, H, I, J, K. Now from A′ D and *d* draw lines to VP2 (this vanishing-point is not shown in the plate, owing to want of space). From A′ set off on the picture-line A′ B′, equal to the length A B in the plan (Fig. 39).

From B′ draw a line to MP2, cutting the line drawn from A to VP2 in *b*.

At *b* draw the perpendicular *b e*, and from *e* draw a line to VP1, cutting the line drawn from *d* to VP2 in *f*; this will complete the general block.

From A′ set off A′ F, and from B′ set off B′ E, equal to the thickness of the wall—shown on the plan.

From E and F on the picture-line draw lines to MP2, cutting A′ *b* in E′ and F′.

At E′ and F′ draw perpendiculars, cutting D *e* in G and H. These will give the inner edges of the walls.

From K draw a line to VP2, which will give the edge of the top step; and from G and H draw lines to VP1, cutting K in *m* and *n*.

From I draw a line to VP2, cutting E′ G in *g*; this will give the front of the lowest step.

From *g* draw a line to VP1, and from F a line to VP2; these, intersecting in *h*, will complete the tread or upper surface of the lowest step.

At *h* draw a perpendicular, and from G draw a line to VP2, intersecting the perpendicular *h* in *i*. This will give the rise or front of the second step.

From *i* draw a line to VP1, and another from H to VP2; these lines will intersect in *j*, and thus complete the second step.

From *j* draw a perpendicular, and from I a line to VP2, cutting the perpendicular *j* in *k*.

From *k* draw a line to VP1, and from J a line to VP2. These, intersecting in *l*, will complete the third step; and a perpendicular, uniting *m* and *l*, will complete the projection.

EXERCISE 23.

Scale, $\frac{1}{4}$ inch to the foot. Height of spectator, 6 feet; distance, 18 feet.

A plane square, the side of which is 8 feet, lies on the ground-plane, with one angle touching the picture-plane at 6 feet on the left of the spectator; its sides recede at angles of 55° and 35°. Give the perspective projection of the square.

EXERCISE 24.

Repeat the previous exercise, but show the figure divided (as for a draught-board) into 64 squares. Colour the divisions alternately.

EXERCISE 25.

Scale, $\frac{1}{4}$ inch to the foot. Height of spectator, 5 feet; distance, 15 feet.

Put into perspective a cube, when one of the edges (4 feet in length) touches the picture-plane at 6 feet on the left of the spectator, and its sides recede at 45°.

EXERCISE 26.

In the same picture, at 5 feet on the right of the spectator, put into perspective a cubical figure 4 feet square at its base and 9 feet high, when one of its edges touches the picture-plane, and its sides recede at 50° and 40°.

EXERCISE 27.

The scale is $\frac{1}{4}$ inch to the foot, the height of the spectator is 6 feet, and the distance 18 feet.

Put into perspective the divided vertical square shown in Fig. 15 (Vol. I., page 365), when its plane is at 50° to the picture-plane.

*** The student is reminded that the lines which in the figure referred to are drawn to the centre of the picture, must in the present exercise be drawn to a vanishing-point on the right side, and that the lines drawn from I J and D, instead of being drawn to the point of distance, must be drawn to the measuring-point.

EXERCISE 28.

All the conditions being the same as in the last exercise, put into perspective the object shown in Fig. 16 (Vol. I., page 365), when the plane of the square side is at 40° to the plane of the picture.

EXERCISE 29.

Scale, $\frac{1}{2}$ inch to the foot. Height of the spectator, 6 feet; distance, 18 feet.

Put into perspective the cross forming the subject of Fig. 24 (Vol. I., page 388), when the point C′ is on the picture-line at 6 feet on the left of the spectator, and when the sides of the containing parallelogram C′ B and C′ E recede at angles of 30° and 60°.

EXERCISE 30.

Scale, height of spectator, and distance the same as in the last exercise.

Put into perspective the block of steps shown in Fig. 23 (Vol. I., page 384), when the point B is at 7 feet on the left of the spectator, and when the object has been so rotated that the line B K recedes from the picture-plane at 50°.

₊ Remember that the distances 1′, 2′, 3′, A″ (Fig. 23) are found by means of the measuring-point, instead of the point of distance, and that all lines which are parallel to each other in the object converge to the same point.

The object of the next study is the same as that in Fig. 33—viz., a pyramidical roof, resting upon four square piers.

the centre of the picture as at C, and draw the perpendicular from it for the line of direction. It will be remembered that as this line represents not only the direction of the central ray, but the distance of the spectator as well, its length will be the same as that between the centre of the picture and the point of distance in Fig. 33.

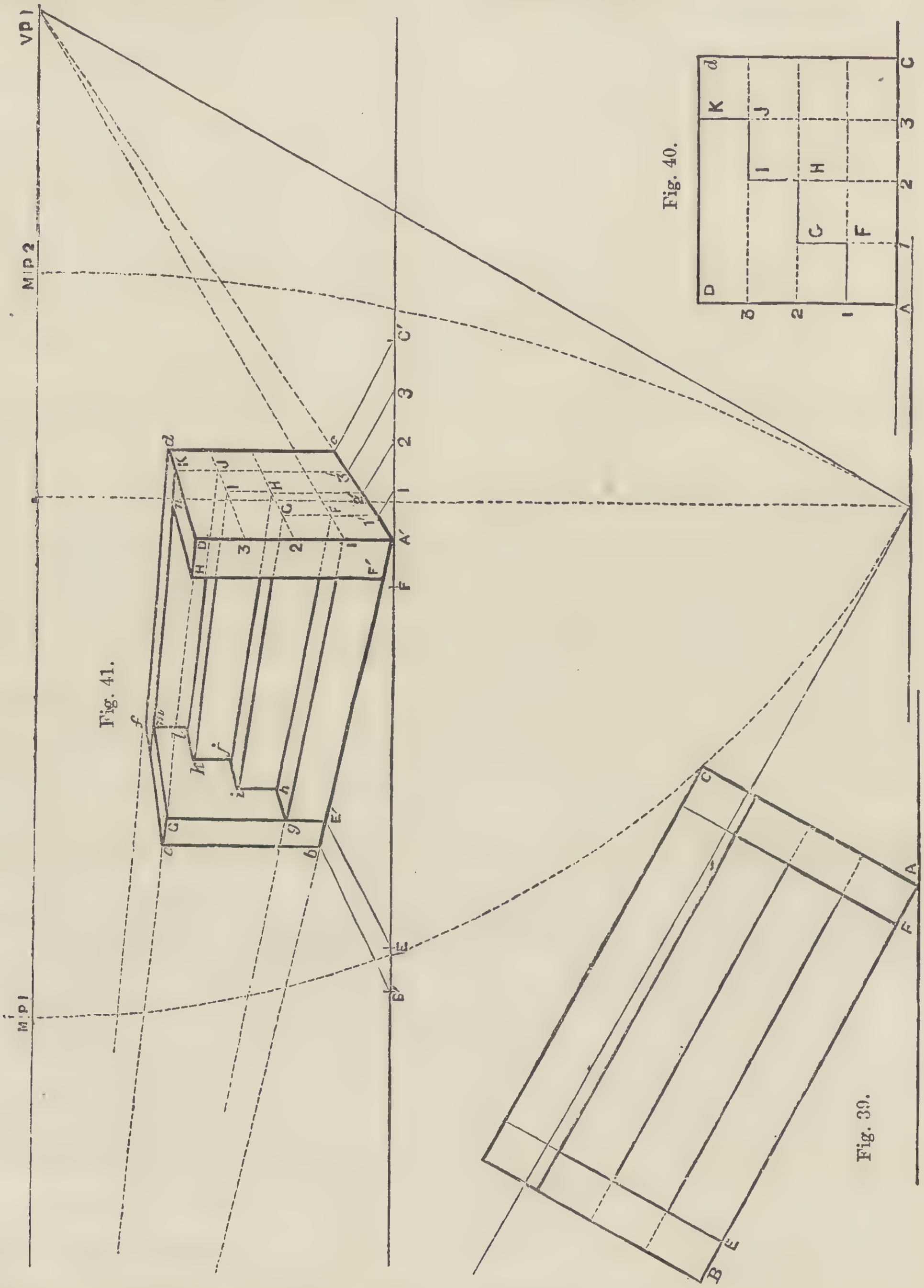


Fig. 40.

Fig. 41.

Fig. 39.

In the present case, however, the object is placed so that its sides are at certain angles to the plane of the picture, whilst in Fig. 33 they were either parallel or at right angles to it.

Fig. 42 is a portion of the ground-plan, to show the angles at which the object is placed in relation to the picture-plane.

The height of the spectator and the distance in Fig. 43 are the same as in Fig. 33.

Having drawn the picture-line and the horizontal line, place

At its lower extremity, S (not shown in Fig. 43), draw a line parallel to the picture-line; and on it, on each side of S, construct angles similar to the angles B A b and C′ A c in Fig. 42; produce the lines forming the angles until they cut the horizontal line. The vanishing-points 1 and 2 (not shown for want of space) will thus be obtained, and from these, with the length extending from the vanishing-points to the station-points, the measuring-points may be marked on the horizontal line.

These preliminaries being settled, place the point A′ at the required distance on the left or right of the line of direction, and from it draw lines to the vanishing-points.

On each side of A′ mark off A′ B and A′ C′, and from B and C′ draw lines to the *measuring*-points, cutting the lines A′ V, A′ V in *b* and *c*.

From *b* and *c* draw lines to the vanishing-points, cutting each other in D.

Then A′ *b* D *c* will be the boundary of the plan.

On each side of A′ set off I and J equal to the true width of the piers, and set off the same width K and L on the inner side

Produce the perpendicular A′ E until it reaches G, the distance E G representing the real height of the pyramid.

Now from F, the intersection of the diagonals in the plan, erect a perpendicular, and from G draw a line to the vanishing-point for the diagonal, cutting the perpendicular F in H; then H is the perspective height of the pyramid. Draw E H, M H, and N H, which will complete the projection.

Exercise 31.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 14 feet.

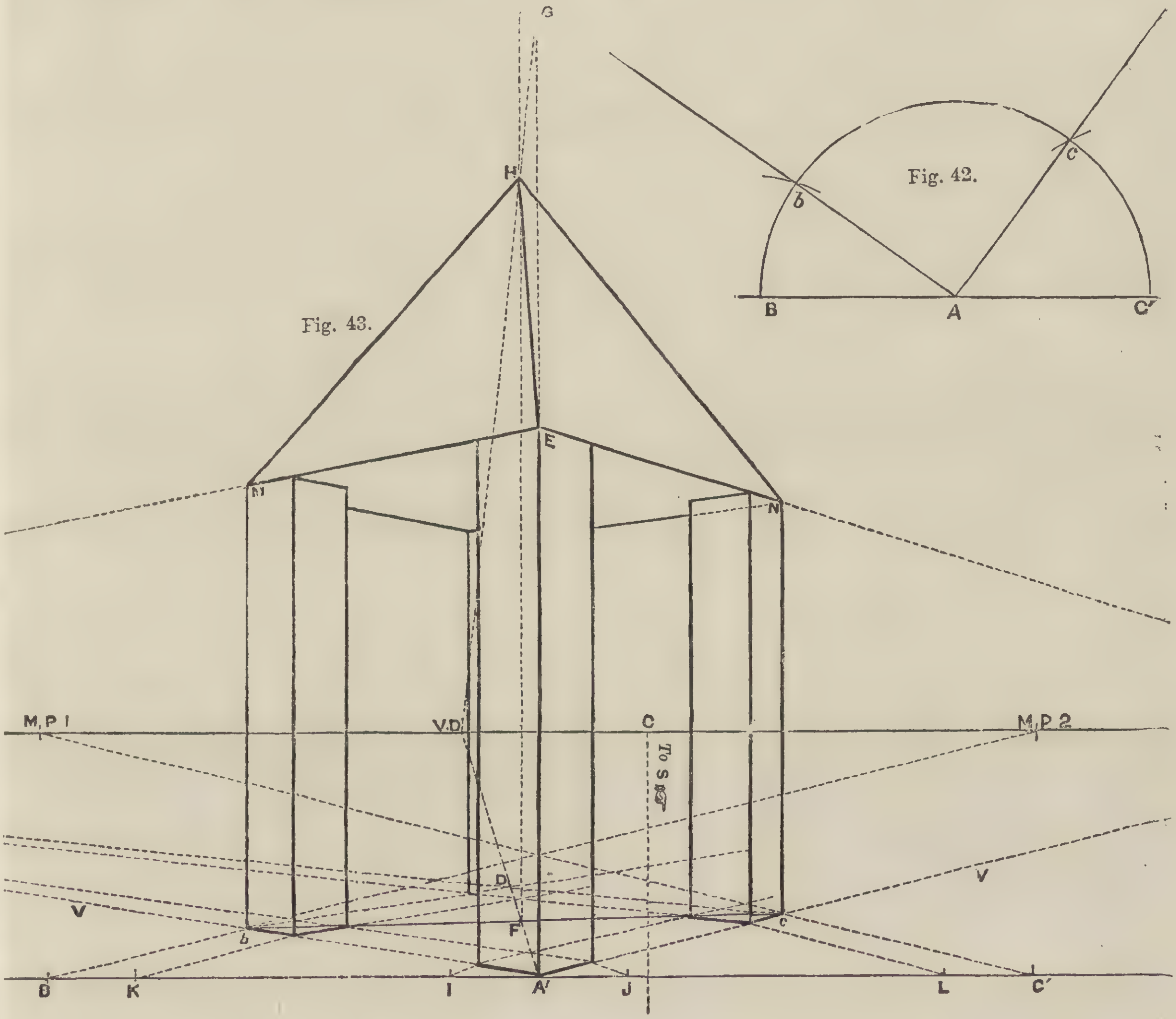


Fig. 42.

Fig. 43.

of B and C′. From I, J, K, and L draw lines to the measuring-point as far as the boundary of the plan, and thence continue them to the vanishing-points. These, crossing, will give the ground-plan of the piers.

Before the figure has become too intricate, draw diagonals in it, and produce the diagonal A′ D until it meets the horizontal line in V D, the vanishing-point for the diagonal, the use of which will be presently seen.

At A′ erect a perpendicular equal to the full height of the piers, and from its extremity, E, draw lines to the vanishing-points.

From *b* and *c* erect perpendiculars, cutting the lines last mentioned in M and N, and from these points draw lines to the opposite vanishing-points; these will complete the perspective view of the under side of the pyramid. The perpendiculars completing the piers are to be drawn from the respective points in the plan, as shown in several previous studies.

There is a structure, consisting of—

1. Four piers, 1 foot square at base, and 12 feet high, forming angle piers of a plan 8 feet square.
2. A slab 8 feet square and 1 foot high, resting on the piers.
3. A pyramid 8 feet square at its base and 5 feet high, resting on the square slab.

The edges of the pyramid and slab are parallel to the sides of the square forming the plan.

Put this object into perspective when its sides are at 35° and 55° to the picture-plane, the nearest angle being on the picture-line, at 6 feet on the right of the spectator.

Exercise 32.

The scale, height of spectator, and distance the same as in the last exercise.

Put into perspective the same object when placed at 5 feet on the right of the spectator, and when standing on a block of stone 8 feet square at base and 1 foot high.

WEAPONS OF WAR.—IX.

BY AN OFFICER OF THE ROYAL ARTILLERY.

RIFLED GUNS.

THE increasing and ever-active tendency to multiply the destructive effects of fire-arms, by increasing their range and precision, and by supplying them with projectiles more and more deadly and irresistible, naturally operated to recommend the conversion of the smooth-bore gun into the rifled gun, just as it had caused the supersession of Brown Bess by the Enfield rifle. Indeed, it may be said that the introduction of rifled small arms rendered it not a matter of choice but a matter of necessity for the artilleryman to develop the weapons of his craft in the same way, and, as far as possible, in the same degree. If artillery was to hold its place at all, it must meet the Enfield and the Minié rifles with a field-piece as superior to those weapons as the old smooth-bore 9-pounder was superior to Brown Bess; and the device by which the infantry soldier's weapon had been rendered so much more powerful was naturally resorted to by the artillerist, to increase proportionally the power of his own particular arm. We had got the rifled musket; it was therefore necessary for us to have the rifled gun. We trust we shall not be misunderstood as wishing to affirm that the rifled gun was first proposed after the introduction of the Enfield rifle, and in consequence of it. Such a statement would be promptly and properly contradicted by antiquarians, who would point to occasional examples of very ancient rifled guns; and by experimentalists, who would remind us of Mr. Joseph Manton's rifled 6-pounder of 1790, of Lieutenant-Colonel Dundas's rifled gun of 1836, of the Cavalli gun of 1846, of the Wahrendorf gun of 1847, of Captain Norton's experiments with rifled cannon, and many others. But the introduction of rifled small arms certainly gave an impetus and earnestness to the exertions to introduce a rifled cannon which had before been wanting, and experiments which had up to that time possessed only a sort of speculative and uncertain interest now became invested with a new power, which drew towards them the attention of the military world.

Before proceeding to enumerate some of the more remarkable devices for communicating a rifled motion to the projectiles of cannon, it may be well to say a few words as to the object of rifling a gun. What is rifling intended to accomplish? What do we gain by it? To this the first answer will perhaps be, We gain the power of firing an elongated instead of a spherical projectile. But this answer would be in part incorrect. It is true, but it is not the whole truth; for we may remind our readers that the first rifled small arm in use in the British service was, as stated in a former paper (Vol. I., page 65), the Brunswick rifle; and the Brunswick rifle threw not an elongated but a spherical belted ball. The first object of rifling a gun or small arm, then, is to obtain rotation on a fixed axis. This object is equally aimed at whether the projectile to be fired be spherical or elongated. In the case of the spherical ball, the rotation upon a fixed axis gives increased accuracy, by eliminating in great measure the errors due to the eccentricity and irregularity of the projectile. Projectiles cannot in practice be made absolutely and uniformly true as to concentricity, weight, and form, and any departure from absolute truth in these points is attended in a ball fired from a smooth-bore piece with a corresponding loss of accuracy. But if a fixed rotatory movement be communicated to that ball, the uncertain rotation due to the position of the centre of gravity will disappear, and with it one source of error; while the inaccuracy due to any irregularities of form and surface will be greatly diminished in consequence of the pressure of the air being more equally distributed around the projectile, the position of which in reference to this air is constantly changing. So that when a spherical ball is fired from a rifled piece we get at once greater accuracy, and this is an advantage which belongs to rifling, whether elongated projectiles be employed or not. But rifling is more valuable as rendering possible the use of elongated projectiles, with all the advantages which flow from their employment. Why cannot elongated projectiles be fired from smooth-bored guns? Because of the pressure of the air acting upon them unequally, and causing them to turn over in flight. "If the centre of gravity of the projectiles be very far forward, it is possible," says Lieutenant-Colonel Owen, in his admirable "Modern Artillery," "to fire them from smooth-bore guns at short ranges." But this is the only case in which an elongated projectile could be fired without rotation; unless, indeed, we could suppose a shot fired in a vacuum, in which case, as there would be no air to press upon it, it would not turn over. If rapid rotation be established upon the longer axis of the projectile, the velocity of rotation will more than counterbalance the pressure of the air, and will prevent the projectile from being turned over. Any one who has amused himself with the gyroscope, or even a child who has played with a top, will know that the spinning motion gives a stability to the axis of rotation which, as long as the spin is strong enough, sets other disturbing forces at defiance. Thus a top or a gyroscope will spin at an angle with the horizon which it could not possibly maintain if it were not in motion. Indeed, a top could not stand at all without being spun, and the wobbling movement which precedes its fall indicates the point at which the force of gravity is beginning to re-assert its sway, and to overcome the failing rotation. These are elementary truths, but they perhaps explain better than more recondite examples the effect of rifling upon a projectile.

Well, then, having advanced thus far—having established that rifling neutralises some of the causes of inaccuracy in the projectile, whether spherical or elongated, and that without it it would not really be practicable to fire an elongated projectile at all—we have to inquire further, what are the advantages of firing elongated projectiles? Those advantages are as follow:—In the first place, weight for weight, the elongated projectile presents a diminished surface for the resisting medium—whether air, or iron, or wood, or water—to act upon. Weight for weight, therefore, the elongated projectile will range and penetrate farther than the spherical projectile of the same material. Or, weight for weight, equal results may be obtained with the elongated projectile with a reduced charge of powder. If the surface of the elongated projectile be increased to that of the sphere with which it is compared, its weight will be greater, and thus it will have greater powers of overcoming an equal resistance. Fourthly, it is often a great advantage to make the striking part of a projectile of a peculiar form and of a peculiar material. The shape of the head will greatly affect the flight; the shape and material of the head will greatly affect the penetrative power. The Palliser projectile of chilled iron would not be possible with an obtuse or hemispherical form of head. It is necessary, as will hereafter be more fully explained, to have a head of a form suitable for neutralising the brittleness of the material, and this is possible with an elongated shot which goes point foremost—it would not be possible with a sphere. Again, the heads of the present Palliser shot are made harder than the bodies, as the gouge or chisel is made harder than its handle. This would not be possible with the sphere. Every projectile in the service has a head of a form which is considered suitable for flight—for cleaving its way with the minimum of resistance and disturbing effect through the air, just as ships are made with bows suitable for easy passage through water. Such an arrangement would not be possible with a sphere. Fifthly, as an elongated projectile meets, in relation to its weight, with less resistance from the air than a spherical projectile, the trajectory of the former will, *cæteris paribus*, be flatter. Sixthly, all elongated projectiles for the same gun can be made of the same *weight*, if desired, so as to be fired with the same charge of powder and the same elevation. With the sphere, all the projectiles for the same gun must be made of the same *size;* and thus the common shell, which is filled with powder, will weigh considerably less than the shrapnel, which is filled with leaden bullets, and will require a different elevation. Seventhly, if a specially long or powerful projectile be required—as, for example, a "double shell"—this requirement can be satisfied with elongated projectiles, it cannot be satisfied with spheres. Eighthly, the fact of a projectile travelling head foremost greatly facilitates the preparation of a suitable percussion fuse, as it is only necessary to provide for action in one direction. This advantage would, it is true, be possessed by the *rifled* sphere, and is therefore rather an advantage of rifling abstractedly than of that particular application of rifling which gives us the elongated projectile. The same may be said of the advantage which rifling gives in respect of shells which are required to act or open to the front in any particular way. Thus, the Palliser shell is required to strike point foremost; the Boxer rifled shrapnel is required to deliver its bullet to the front.

The advantages of rifling may therefore be summed up, as pointed out by Captain Orde Browne, R.A., in his "Treatise on Ammunition for Rifled Ordnance," as follow:—

1st. Accuracy.

2nd. Simpler action of percussion or concussion fuses.

3rd. Distribution of the metal with a view to the special requirements of each projectile.

The above advantages apply whether the rifled projectiles be spherical or elongated.

Then, from the use of elongated projectiles, which rifling renders possible, we get,

4th. Power of making the head of any form required.

5th. Greater range or penetration.

6th. Saving of powder.

7th. Flatter trajectory.

8th. All projectiles for the same gun may be brought to the same weight.

9th. If required, a specially heavy projectile may be given to any gun, for exceptional use.

These are the advantages which we realise from rifling our guns. Let us now pass on to observe in what way this rifling has been proposed to be accomplished.

To most persons the idea of rifling almost necessarily suggests a gun with grooves cut in it, and shot furnished with studs or other projections to fit those grooves. But although this may be the simplest and most natural way of rifling a gun, it is very far from being the only way. The Whitworth gun, for example, has no grooves, properly so called, and no projections upon the shot. It is, roughly speaking, a spirally hexagonal bore, which fires a spirally hexagonal shot. The Lancaster gun had an oval bore, and fired an oval shot. Then there have been numerous propositions for reversing the ordinary method of rifling, and making the grooves in the shot, with corresponding projections in the gun. But it is not necessary that the gun should be rifled at all. The Mackay gun is a smooth-bore, which fires a grooved projectile, the rush of gas along these grooves being supposed to communicate a rotatory motion to the projectile. Many proposals have been made for communicating rotation by the pressure of the air upon the projectile after it has left the bore, by acting on oblique planes or channels, either in front or in rear of the shot. The Museum of Artillery at Woolwich contains many specimens of each of these different modes of rifling. Looking at them broadly, we shall find that they may be classified, as pointed out by Lieutenant-Colonel Owen, under three heads:—

1. Mechanical means inside the bore of the gun.
2. The action of the powder-gas upon the shot inside the bore.
3. The action of the air upon the projectile after it has left the bore.

The common object which all proposers of systems of rifling have had in view, is the spinning of the projectile on its longer axis, and with that axis as nearly as possible coincident with the axis of the bore or its prolongation. It is important to do this in a manner the least injurious to the guns, which will permit of easy loading, and which will impose no serious mechanical difficulties upon the manufacturers of the guns and projectiles. To discuss the merits and demerits of the various systems of rifling would occupy more space than can now be afforded, and would be beyond the scope of these papers. Indeed, allusion has been made to the various experimental modes of communicating a rotatory motion to projectiles chiefly to warn those who may contemplate the trial of some supposed novelty in rifling that they will do well first to inspect the valuable collection of rifled projectiles which exists at Woolwich, and to learn from them the proportion of failures to successes.

The system of rifling of which it is first necessary to make mention at this stage of the subject is that employed by Sir William Armstrong in his original guns. The Armstrong shot were coated with a leaden coating, slightly larger than the bore, and which on the explosion of the charge became forced into the numerous shallow spiral grooves with which the guns were provided, and which thus spun the projectile. The advantages of this system, the *système forcée* (as the French call it), are that it gets rid of windage, that it ensures complete centreing of the projectile, and that it gives great accuracy. *Per contra*, the system is one which entails the use of lubricators, it imposes a great strain upon the gun, it is very costly, on account of the price of the lead-coating, and the lead-covered projectiles are very liable to get disfigured in transport. Moreover, when lead-coated projectiles are fired against armour-plated ships, the lead coating, although it has increased the momentum of the shot, acts as a bar to its free progress through the plate, and thus lessens its power of penetration. The difficulties which were at first experienced in connection with the firm attachment of the lead-coating have been overcome by the adoption of the plan proposed by Mr. Bashley-Britten, of soldering on the lead with zinc solder, instead of attaching it mechanically. All the breech-loading guns in the English service fire lead-coated Armstrong projectiles.

The muzzle-loading guns fire studded shot, and are rifled with three or more grooves, according to their size. An ingenious system of grooving, known as the "shunt" system, which was designed by Sir William Armstrong, is fast dying out, and hardly calls for notice. It is merely necessary to observe that with this system the shot loaded easily on the deep side of the groove, and in coming out hugged the opposite or "driving" side, being "shunted" in its passage up the bore of to a shallower level. The objection to this system was that it was apt to strip the studs off the projectile, by throwing on to them a sudden strain at the moment when the shot took the shallower level. In some instances it is considered the strain acted injuriously upon the gun.

The "Woolwich" guns—by which is meant all our heavier muzzle-loading rifled guns—have a groove very nearly akin to that used in the French guns. In some cases the spiral is made uniform throughout the bore; in the majority of cases it is quicker at the muzzle than at the breech. The supposed advantage of the increasing twist is that it slightly diminishes the strain upon the gun. The projectile meets with little or no resistance from the grooves at the instant when it is propelled forward by the ignition of the charge, and it is only as the projectile travels forward in the bore that the resistance due to rifling becomes sensible. But this resistance is far less than is commonly supposed, and it is doubtful if the increasing spiral really affords anything like that amount of relief to the guns which was at one time believed. It is considered that the increasing spiral gives also greater accuracy of fire.

In the field guns the form of groove is rather different from that of the Woolwich guns, and the play between the studs and grooves is less. But these are details with which it is not necessary to encumber the present papers. It will be sufficient to observe that there are two main systems of rifling in vogue in the British service—namely, the system of many shallow grooves, with lead-coated projectiles, for the breech-loading guns; and the system of few deep grooves, with studded projectiles, for the muzzle-loading guns. The *rationale* of rifling has also been explained, and the advantages which it gives us have been set forth. We will in our next paper pass on to the construction of our rifled guns, and show the principles upon which they are built.

PRINCIPLES OF DESIGN.—XIV.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

DECORATION OF CEILINGS (*continued*).

In my last article I noticed that the decoration of a room should be in character with its architecture, but that while this should be so, the ornament applied by way of enrichment should not be a servile copy of the decorative forms employed in ages gone by, but should be such as is new in character, while yet of the spirit of the past.

Many circumstances tend to determine the nature of the decoration which should be applied to a ceiling: thus, if a ceiling is structurally divided into square panels, the character of the ornament is thereby restricted, and should these panels be large, it will probably be desirable that each be fitted with the same ornament; while if they are small three or four different patterns may be employed, if arranged in some orderly or methodical manner.

A ceiling may also have the joists or beams visible upon it: in this case the decoration would have to be of a very special character. The bottoms of the joists might have a string pattern upon them (a running pattern), as the Greek "key," or guilloche; whilst the sides might have either a running pattern, or a pattern with an upward tendency, as the "Greek

honeysuckle;" and the ceiling intervening between the joists might have a running pattern, or better, a star, or diaper pattern, or it might have bands running in the opposite direction to the joists, so as, with them, to form squares, which squares might be filled with ornament.

If, however, the ceiling is flat, and is not divided into sections structurally, almost any "setting out" of the surface may be employed, as Fig. 40; or a large centre ornament, as Fig. 41; or a rosette distributed over the entire surface, as Fig. 42. In any case it is not necessary or even desirable that the ornament be in relief upon the ceiling. Flatly treated ornaments may be employed with advantage, and all fictitious appearance of relief must be avoided.

There are so many different ways of setting out ceilings, that I cannot attempt even to make any suggestions. I would simply say, however—Avoid an architectural setting out, if there are no structural members; for ornament which is flat may spread in any manner over a surface without even appearing to need structural supports. As to the colour of a ceiling, if there is to be no ornament upon it, let it be a cream colour (formed of white with a little middle chrome) rather than white. Cream-colour always looks well upon a ceiling, and gives the idea of purity. A grey-blue is also a very desirable colour for a ceiling, such as is formed of pale ultramarine, white, and a little raw umber, just sufficient to make the blue slightly grey (or atmospheric). In depth this blue should be about half-way between the ultramarine and white. Another effect which I like is produced by the full colour of pure (or almost pure) ultramarine. In this case the cornice should be carefully coloured, and pale blue and white should prevail in it.

A further and very desirable effect is produced by placing pale cream-coloured stars irregularly over the pale blue, or even the deep blue ceiling, or by placing pale blue stars upon the cream-coloured ceiling. The stars should vary for an ordinary room ceiling (say a room sixteen feet square by ten feet high) from about three inches from point to point down to one inch; the larger stars having six points; others being smaller and with five points; and the small ones having, some four points, and some three. If such stars are irregularly (without order) intermixed over the ceiling, and yet are somewhat equally dispersed, a very pleasing and interesting effect will thereby be produced. This effect is in much favour with the Japanese.

Fig. 41.

Another good effect is produced by giving the ceiling the colour of Bath or Portland stone, and starring it with a deeper tint of the same colour. This effect is improved by each star having a very fine outline of a yet darker tint of the same colour.

I should recommend those interested in the decoration of ceilings to study carefully the Egyptian, Alhambra, and Greek Courts at the Crystal Palace, Sydenham, especially the two last named; also to notice the ceiling in St. James's Great Hall, Piccadilly, London, and the ceiling of Ushaw College chapels near Durham. The ceilings in the Oriental Courts, by Mr. Owen Jones, at the South Kensington Museum are worthy of careful notice; but the Renaissance ceilings in other parts of the Museum are both wrong in principle and bad examples of their style. The structurally formed glass ceiling of the Crystal Palace Bazaar in Oxford Street, London, and still better, the ceiling of Mr. Osler's glass warehouse in Oxford Street, are well worthy of note.

On the Continent we very frequently meet with ceilings on which large pictures have been painted, as in the Louvre and the Luxembourg in Paris; and the authorities of the South Kensington Museum are making efforts to introduce this style into England, but such pictorial ceilings are in every way wrong.

1st. A ceiling is a flat surface, hence all decoration placed upon it should be flat also.

2nd. A picture can only be correctly seen from one point, whereas the decoration of a ceiling should be of such a character that it can be properly seen from any part of the room.

3rd. Pictures have almost invariably a right and wrong way upwards. A picture placed on a ceiling is thus wrong way upwards to almost all the guests in the room.

4th. In order to the proper understanding of a picture you must see the entire of its surface at one time; this is very difficult to do without almost breaking your neck, or being on your back on the floor; whereas, an ornament which consists of repeated parts may render a ceiling beautiful without requiring that the whole ceiling be seen at the one glance.

Fig. 42.

Most of the French pictorial ceilings are so painted that they are properly seen when the spectator stands with his back close to the fire. This is very awkward, as the rules of society do not allow us to stand in this position before company. Pictorial works are altogether out of place on a ceiling; they ought to be framed and hung right way upwards upon walls where they can be seen. We have a painted ceiling at the Greenwich Hospital.

Arabesque ceilings, such as that of the Roman Court at the Crystal Palace, are also very objectionable.

What can be worse than festoons of leafage, like so many sausages, painted upon a ceiling, with griffins, small framed pictures, impossible flowers, and feeble ornament, all with fictitious light and shade? But not content with such absurdities and incongruities, the festoons often hang upwards on vaulted or domed ceilings, rather than downwards. Such ornaments arose when Rome, intoxicated with its conquests, yielded itself up to luxury and vice rather than to a consideration of beauty and truth.

Decorations like these were to an extent again revived by the great painter Raphael; but it must ever be remembered that Raphael, while one of the greatest of painters, was no ornamentist. It requires all the energy of a life to become a great painter; and it requires all the energy of a life to become a great ornamentist; hence it is not expected that the one man should be great in the two arts.

In all ages when decorative art has flourished, ceilings have been decorated. The Egyptians decorated their ceilings, so did the Greeks, the Byzantines, the Moors, and the people of our Middle Ages, and a light ceiling appears not to have been esteemed as essential, or as in many cases desirable. It is strange that so few of our houses and public buildings contain rooms with decorated ceilings; but the want is already felt, the fashion has set in, and many are at this present moment being prepared. We must get simple modes of enrichment for general rooms—modes of treatment which shall be effective, and yet not expensive — and then we may hope that they will become general.

The large centre ornament for ceilings shown in Fig. 41 is necessarily given in portions, but students of decorative art are recommended to copy and complete these drawings in their entirety, as useful studies of symmetrical design, and for practical purposes to draw them on a large scale on cartridge paper, and colour them according to the rules already laid down, that they may be able to judge fairly of the general effects produced.

Fig. 40.

APPLIED MECHANICS.—XII.

BY ROBERT STAWELL HALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

THE PLANING MACHINE.

In the last lesson we introduced the important principle of the slide-rest as applied to the turning lathe; in the present lesson we shall consider the no less important application of the slide-rest to the planing machine. The lathe affords the means of obtaining surfaces of revolution, the planing machine enables us to produce planes with wonderful precision. When we consider that nearly all the acting surfaces of machines are either planes or surfaces of revolution, the importance of the slide-rest in producing such surfaces becomes manifest.

In the planing machine the work is moved while the tool remains at rest, thus differing from shaping and slotting machines, in which the work remains at rest while the tool is moved.

The planing machine consists of a table which is adapted to slide on two grooves, so that all parts of the table move in parallel lines. On this table the work is placed, and secured in the proper position by screws. The work thus traverses backwards and forwards with the table; attached to a frame above the table is the slide-rest, which carries the tool. The point of the tool traces out a straight line upon the work which moves beneath it, and if, therefore, at the conclusion of each cut the point of the tool be advanced in a straight line, so as to take a fresh cut, a plane surface will be produced upon the work.

There are many ingenious mechanical contrivances in the planing machine, both for producing the return motion of the work, and also for making the tool self-acting. These we shall describe.

We take the following very interesting passage from Mr. Nasmyth's remarks upon the use of the slide-rest (see "Baker's Mechanism," p. 227):—"There is no form which is so frequently required and essential to any piece of mechanism as the plane surface, or rectangular prismatic forms generally. The vast expense attendant upon the production of such by the tedious and unsatisfactory process of chipping and filing caused every engineer to avoid by all means any arrangements which rendered such forms necessary, however essential they might be to the perfect action of the machine. It is quite laughable to observe in any old piece of mechanism the niggardly use of those important forms, arising from the above obstacle. The introduction of the planing machine at once altered the entire system, inasmuch as forms and arrangements became practically possible which formerly the engineer dared not think of using; this was simply following out in the plane surface what the slide-rest had produced in the turning-lathe as regards cylindrical forms. And the result was that not only was the machinery produced by its agency most strikingly superior by its direct influence, but also that the planing machine enabled us to produce improved tools at a greatly reduced cost. That mighty influence in all affairs, the first planing machine, enabled us to produce the second still better; that again produced a better still; and then slide-rests of the most perfect kind came streaming forth from them, and they again assisted in making better still; so that in a short time a very important branch of engineering—namely, tool-making—arose, which had its existence, not merely owing to the pre-existing demand for such improved tools, but, in fact, raised as it were upon a demand of its own creating, and all this caused by the slide-rest and its offspring, the planing machine. One has only to go into any of those vast establishments which within the last thirty years have sprung up for the purpose of supplying the demand for machinery, and we shall find that nine-tenths of all the fine mechanisms in use and in process of production are through the agency, more or less direct, of the slide-rest and planing machine."

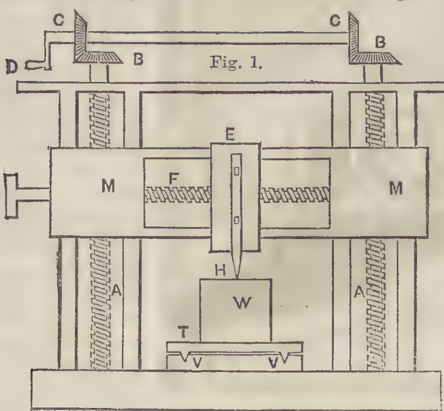


Fig. 1.

We shall first describe the mechanism by which the motion of the tool secured in the slide-rest can be obtained. A diagrammatic view of a planing machine is given in Fig. 1. T is the table sliding on V grooves (we shall consider its motion presently); W is the work upon which a plane surface is to be produced. The table is furnished with a number of slots, and the work is secured to the table by means of bolts of various forms, the heads of which are underneath the table, while the shanks pass through the slots; brackets and other ingenious contrivances are used for securing work of different forms. The reciprocating movement of the table is thus partaken of by the work, and as the table moves the work, the point of the tool, H, takes off a shaving. The tool is attached to a slide, E; on E is a nut in which the screw F works; the frame M M is horizontal; consequently, when the screw F is made to rotate by the handle N, the point of the tool is moved in a horizontal line perpendicular to the direction of motion of the table. After each cut has been taken the tool is moved a little, and then on the return of the table a fresh cut is taken. Thus the movement of the table, compounded with the movement of the tool, develops a plane surface upon the work. In order to economise labour, and still more to secure regularity and perfect uniformity in the work, the tool is not generally moved by the hand of the workman.

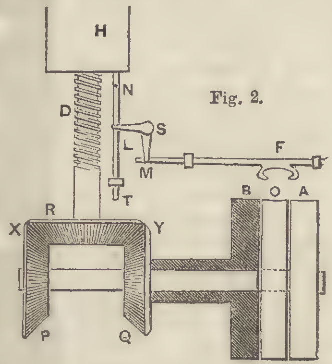


Fig. 2.

By means of a simple contrivance, the table itself, after the conclusion of each cut, and before the commencement of the next, turns the screw F, a little, thus making the machine self-acting.

In order to accommodate the tool to the varying dimensions of the work which the planing machine may receive, the frame, M M, is itself able to receive a vertical motion. The vertical screws, A, A, work into nuts on the back of the frame, M M; these screws have small bevelled wheels, B, B, keyed upon them; these bevel wheels are equal, and are turned by the two equal bevelled wheels, C, C. Thus, by turning the handle D, the whole frame, M M, can be raised or lowered at the commencement of the work, in order to place the tool at the required height. It will, of course, be understood that during the process of planing the position of the frame M M must not be altered.

We have now to describe the mechanism by which the table is moved. The problem we have to solve is more complicated than the simple motion of revolution which has to be produced in the lathe. The table has to be moved backwards and forwards, and the extent of its motion must, in order to save time, be accommodated to the length of cut. In some planing machines the support which carries the tool is capable of being turned round, so that on the return of the table a cut may be taken as well as in the forward motion. Other machines have not this contrivance; but the table is brought back by a more rapid movement than it would be possible to use for planing: thus the loss of time on the return is reduced to a minimum.

In Fig. 2 is a diagram of a planing machine in which the tool is intended to be turned round, so that both motions are performed with equal velocities.

The table is moved by a screw which revolves beneath, and works into a nut attached to the table. This screw is shown at D; H is the table. We have only shown in this figure the portions which relate to the motion of the table. The screw is attached to a bevelled wheel, R; this wheel, R, may be turned

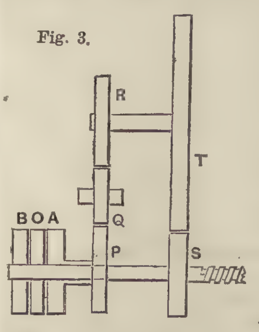
by either of the wheels, Q and P, into which it gears. The wheel Q is attached to the pulley B; Q and B turn together quite freely upon the shaft. When the band which drives the planing machine is upon B, the wheel Q is turned, and this makes the screw revolve. Of course R will turn round P in the opposite direction to that in which Q rotates. But now let the band be shifted from the pulley B to the pulley A. A will now be driven round, and with it P, because P and A are both keyed upon the same shaft, which passes freely through B and Q; hence the bevelled wheel R, and therefore the screw, will now be driven by the wheel P. It will be easy to see that R will move in opposite directions, according as it is turned by P moving in one direction or Q moving in the same direction. Suppose, for example, that the wheel P turn so that the part of it near X descends, then the part of R at Y ascends, whereas had the motion been given by Q, the part Y descends, of course making the part near Y on R descend; hence we have a most convenient means of reversing the table by just shifting the band from one pulley to another; between the pulleys A, B is a third pulley, O. This is what is called an idle pulley, because it turns freely on the shaft. The band is therefore turned on this pulley when it is desired to throw the machine out of action.

We have now to describe that very ingenious portion of the mechanism whereby, when the table has arrived at the end of its stroke, it changes the band from B to A, and thus itself reverses the motion. Underneath the table is a rod, N L T. One of the guides which restrain this rod to a motion parallel to the table is shown at T. A stud upon the rod is shown at N; this stud can be attached by a screw to any point of the rod. The table in advancing towards R comes in contact with N, and thus pushes the rod N L T forwards. A pin upon the rod at L works in a slot in a bell-crank lever, M S L. A second pin, fixed to M F, works in a slot in M S. We have already described the bell-crank lever in our lesson upon the lever; it gives a convenient method for changing motion from one line to another line perpendicular to it. When L is pushed on, it is evident that M will act on the rod M F; but M F carries a fork O, through which the band passes; thus the band will be carried from the wheel B to the wheel A. The table will then commence to move in the opposite direction until it meets a second stud on the rod T L N, which serves to bring the band back again to B. Thus the table will reciprocate without the attention of the workman. The position of the studs upon the rod N T is to be determined by the length of cut which is required. The reversal of the tool at the conclusion of the cut before the table commences to return can also be effected by a self-acting apparatus.

In the best planing machines, which are used when very superior work is required, a quick return motion is considered preferable to the reversal of the tool, notwithstanding the sacrifice of time that is involved. Various ingenious mechanical contrivances are made use of for the rapid return motion. One of the most useful of these is shown in Fig. 3.

O is an idle wheel, and A and B are the pulleys which move the table. When the band is on B the motion of the screw is slow in one direction, but when the band is on A the screw revolves rapidly in the other direction. The arrangement for shifting the band is the same as that we have already described; so this diagram merely shows how the difference between the velocities of advance and return is obtained.

Fig. 3.



The pulley A is attached to the toothed wheel P; so that when A is turned, P must turn with it; these wheels turn freely upon the shaft. Q and R are also toothed wheels. We shall suppose that P and R are of the same magnitude, the size of Q being indifferent. P and Q revolve in opposite directions, so do Q and R; therefore P and R revolve in the same directions, and, since they are equal, with equal velocities. T is a large-toothed wheel on the same shaft as R. We shall suppose, for the sake of illustration, that T has sixty teeth. T revolves, therefore, in the same direction as P, and they each perform one revolution in the same time. T gears into a wheel, S; this wheel is upon the screw which moves the table. If S have twenty teeth, it will turn round three times for each revolution of T, and, of course, in the opposite direction. Hence S turns round in the opposite direction to the motion of P, and revolves three times when P has turned round once; this corresponds to the return motion of the table. But when the band is shifted from A to B by the fork, the motion is reversed. The shaft on which B is keyed is a continuation of the screw S, and hence the screw revolves in the same direction as the motion of B, and with the same velocity. Thus the table is brought back three times as fast as it is advanced.

VEGETABLE COMMERCIAL PRODUCTS.
XX.

MISCELLANEOUS PLANTS OF COMMERCIAL VALUE (*continued*).

COQUILLA NUT (*Attalea funifera*; natural order, *Palmaceæ*).—This is the fruit of a South and Central American palm. It is a nut of not more than three inches in length and two in breadth, and is completely solid, excepting a small cavity in the centre, in which the seed is deposited. The shell is therefore very thick, and it is also very hard, taking a fine polish. Coquilla nuts are used chiefly by ornamental turners for the production of small knob handles for cabinet drawers, parasol and umbrella handles, chessmen, rings, brooches, and small toys. About 300,000 nuts were imported in 1852.

MARKING NUT (*Semecarpus anacardium*; natural order, *Anacardiaceæ*).—A native of the East Indies. This nut, somewhat like a tamarind stone, has an exterior covering formed of two laminæ, between which is a caustic bitter juice staining an indelible black, and which is much used as a black varnish, as well as for marking linen, whence its name, "marking nut." It is imported into this country for these purposes.

ORRIS ROOT (*Iris Florentina*; natural order, *Iridaceæ*).—This plant is a native of Italy, and cultivated in gardens. Orris root is used as an ingredient in tooth powders, and in the perfumed preparation of wheat starch called violet powder. About five tons are annually imported.

CRABS' EYES (*Abrus precatorius*; natural order, *Leguminosæ*).—This is a pretty climbing plant, a native of the West Indies. Its seeds are bright scarlet, jet black round the hilum, and very handsome. In India they are used by druggists and jewellers as weights, being almost uniformly one grain. They are also strung together for necklaces and rosaries.

RATTANS (species of *Calamus*; natural order, *Palmaceæ*).—These palms yield the canes or rattans of commerce. They have very long slender stems, with leaves at considerable distances apart, and the climbing species reach the tops of the highest trees by means of the powerful whip-like prolongations from the midribs of the leaves. The stems contain a considerable amount of silex, which renders them hard and gives them a glossy appearance. *C. rudentum* produces stems 300 feet in length, which make excellent ropes of immense strength, and as such are used by the native Hindoos in catching elephants. *C. Scipionum* furnishes the walking-sticks known as Malacca canes. *C. rotang*, *C. rudentum*, *C. verus*, *C. viminalis*, and others, are used in this country for the bottoms of chairs and couches, the sides of carriages, etc.; and in India are made into baskets, mats, hats, and other useful articles. They are also used as ropes and cables, in the junks and coasting vessels, and take the place of chains in native suspension bridges.

The rattans are found in commerce in bundles, each cane being once or twice doubled up in order to make the bundle smaller and more compact; the canes are very seldom less than twelve or even sixteen feet in length. About 75,000 bundles of canes, 100 canes being in each bundle, or 7,500,000 canes, are annually imported into the United Kingdom. Holland also imports annually several million pieces. Bengal, Arracan, and the Sunda islands produce the greatest quantity of rattans, and Europe is supplied *viâ* London, Amsterdam, and Rotterdam.

BAMBOO (*Bambusa arundinaceæ*; natural order, *Gramìnaceæ*).—This gigantic tropical grass is extensively spread over India, China, and Japan. It grows like a tree, shooting up with great rapidity in two or three months to a height of fifty or sixty feet. Its hollow stems, which attain a diameter of seven or eight inches, are much used for building purposes in the countries where it grows, and its young shoots serve as walking-canes. The Chinese make from the inner bast-like bark an inferior kind of paper.

TECHNICAL DRAWING.—XXXII.

DRAWING FOR MACHINISTS.

THE STEAM-ENGINE (*continued*)—THE GOVERNORS.

It will be found that this portion of our series of lessons in Technical Drawing supplements in a great measure the lessons on the Steam-engine given in this work. In these the machinist and engineer will find practical working drawings of different parts of the steam-engine, while in the papers to which we have just alluded the student may derive the necessary instruction respecting the different forms of steam-engines, with an accurate description of the purposes which each component part and special feature tends to serve. In the present lesson we shall describe the governors.

The governors are an important part in the details of a steam-engine, and form an excellent study for mechanical drawing. Their use is to regulate the speed of an engine and keep it uniform, and they perform this duty by closing the throttle-valve before mentioned (Figs. 304, etc.), and so shutting off some of the steam. The governors are really a pair of conical pendulums, and when put in rotation the centrifugal force of the balls, or their tendency to fly outwards, increases as they revolve faster. They are suspended by the upper end of the pendulum-rod, and so must rise higher if they fly outwards; at first a very slight elevation accompanies their extension, but afterwards the elevation becomes greater and greater for every further extension. As the action of gravity is constant, and not affected in any way by their revolution, there will be two balanced forces at work: one, the centrifugal power of the balls; and the other, gravity; one variable with the speed of the engine, and the other constant. The combined operation of these forces regulates the position of the balls, and they are connected with the throttle-valve so that an opening for the admission of steam is made to increase as the governor-balls fall down, and to diminish as they rise, thus regulating the quantity of steam, and thereby the engine's speed.

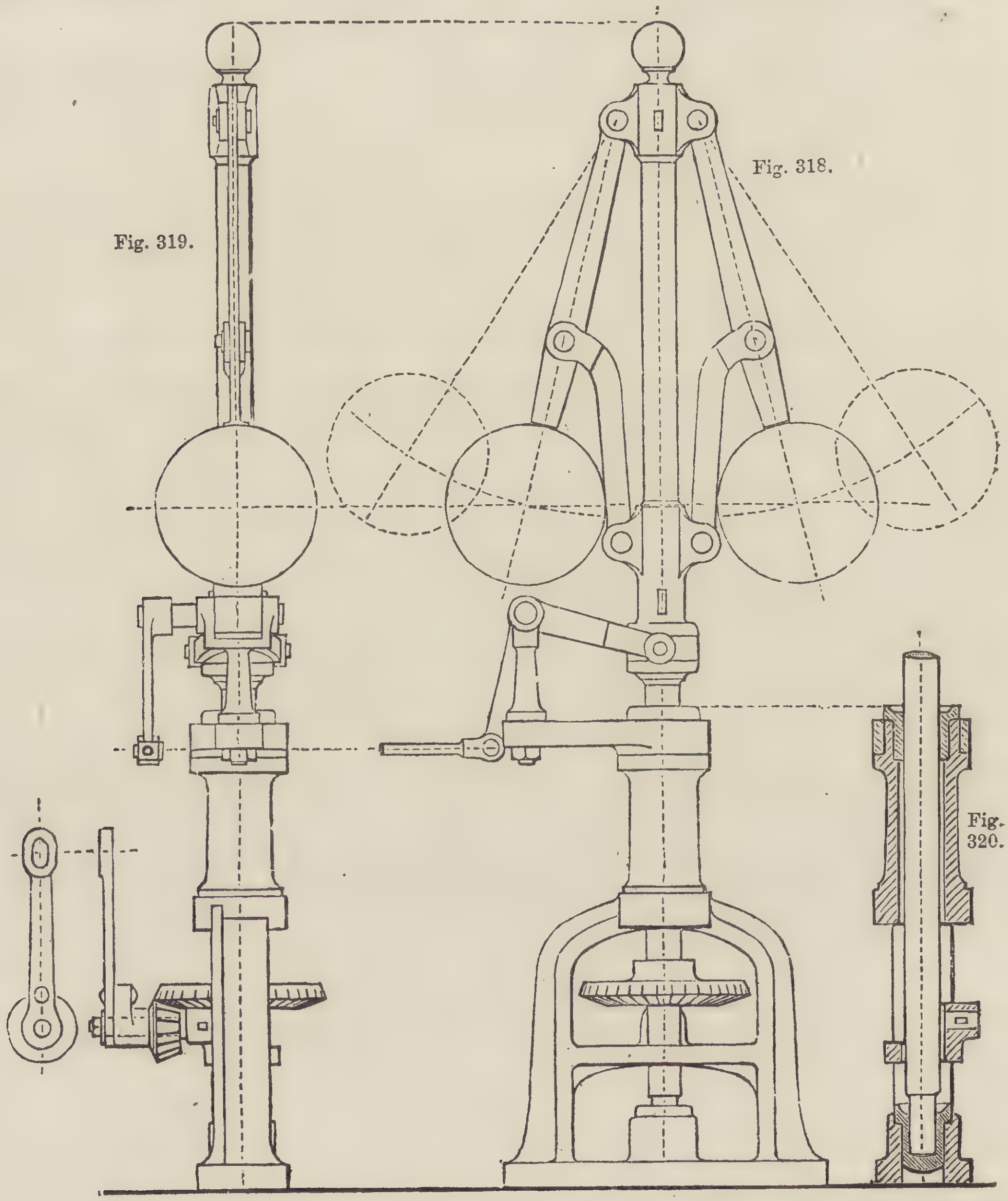


Fig. 318.

Fig. 319.

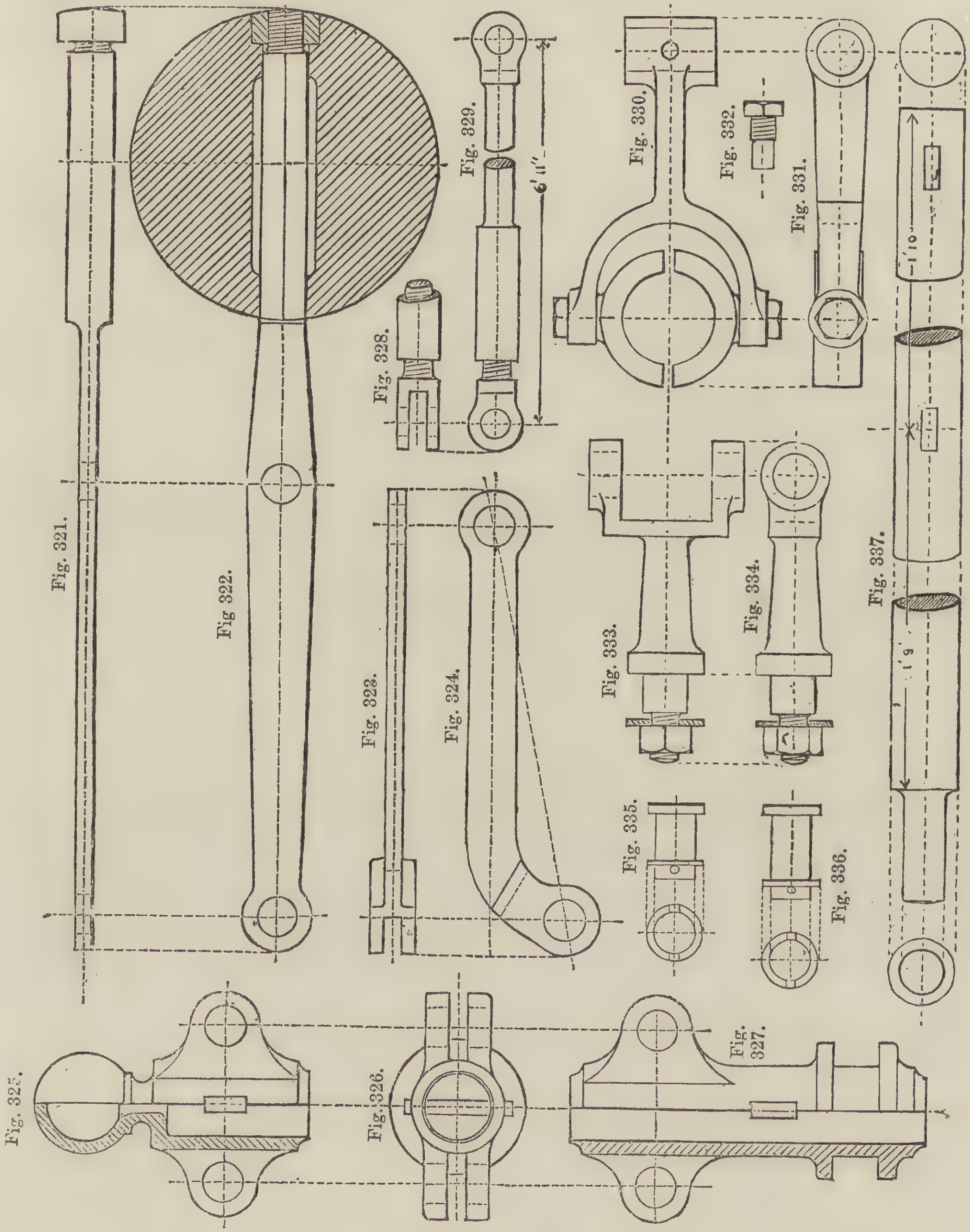
Fig. 320.

Figs. 318 and 319 are front and side elevations of the governor; and Fig. 320 a vertical section of its standard or

supporting pillar, which is bolted upon the planed bed of the engine. Brass bushes are fitted into the upper and lower ends in which the vertical governor spindle revolves.

Figs. 321 and 322.—Pendulum and ball; two views of the former and one section of the latter. Inside the ball is a slightly enlarged cavity, so arranged that by filing the ends of lengthen or shorten it, and so adjust the working of both governor and throttle-valve to each other.

Figs. 330 and 331.—Lever, made of brass, with two crescent-shaped pieces of steel to fit between the sliding-block collars, and transfer its movement to the throttle-valve lever, represented in the preceding lesson (Fig. 308).



the square hole it will fit the corresponding square part of the pendulum-rod, without the labour of filing the entire hole.

Figs. 323 and 324.—Two views of the link connecting the pendulum and sliding-block.

Figs. 325, 326, and 327.—The brass cap and sliding-block, shown partly in section and elevation, with one plan which suits almost exactly for both.

Figs. 328 and 329.—Throttle-valve rod, with a screw to

Fig. 332.—Pin for slide-block lever and steel pieces.

Figs. 333 and 334.—Support for the above lever.

Fig. 335.—Pins for cap, slide-block, and pendulum, all made of steel, or of wrought iron case-hardened—that is, coated with steel by a chemical process.

Fig. 336.—Similar pins for the pendulum.

Fig. 337.—The vertical spindle to carry the pendulum, made of iron, except at the lower end, which is steel.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XI.—CHARLES HUTTON, LL.D.

BY JAMES GRANT.

CHARLES HUTTON, one of the most eminent mathematicians England has produced, was born in 1737, during the reign of George II. His parents were in humble circumstances, and very poor; they toiled early and late, and seemed only to exist to carry on that endless warfare with indigence which is all the needy know the word "life" to mean. He lost his father in boyhood, but having picked up a smattering of education, together with the science of measurements, he commenced in his eighteenth year to teach mathematics in the village of Jesmond, near Newcastle, and while there became so close and zealous a disciple of the Methodists that he even ventured, not only to write sermons, but to preach them to the people. This religious enthusiasm left him, however, on his removal to Newcastle, whither he was drawn by the increasing number of his pupils and his own growing proficiency as a teacher; and among those who attended his classes he had the pleasure to reckon the late Lord Chancellor Eldon. He found time for investigation and composition amid the multiplicity of his occupations, and in 1764 published a treatise on "Arithmetic and Book-keeping," for the use of schools. Since then it has gone through many editions; but it may be interesting to mention that in printing the first one, to supply the proper mathematical types, which would not then be found in a provincial town like Newcastle, Hutton had with his own hand to fashion, by the aid of a penknife, on the reversed ends of old types, all the algebraical characters used in the vulgar fractions and other parts of his treatise.

A more elaborate and abstruse work, "A Treatise on Mensuration in Theory and Practice," next occupied his leisure time. Prior to this publication, the works on mensuration used in seminaries were those of Hawney and Robertson; the former, inaccurately and inelegantly written, showed few attempts at theory; the latter, a more correct and perfect work, was limited to the exhibition of rules and examples. There had been from an earlier period, especially since the invention of fluxional analysis, many treatises and books relating to rectifications, quadratures, and cubatures written by learned men at home and abroad; but to collect, combine, and reduce all these to order and method, to expunge what was erroneous, curtail what was verbose, elucidate what was obscure, and develop practical results with perspicuity, became the task of Hutton, whose quarto volume, which appeared in 1770, was a masterpiece of its kind. Fortunately for him, about this time the Professorship of Mathematics in the Royal Military Academy at Woolwich became vacant, and the Master-General of the Ordnance (the Marquis of Townsend) directed that any individual who, at a public examination, should prove himself qualified to discharge the duties of that chair should be appointed to fill it. Colonel Edward Williams, a scientific officer of the Royal Artillery, now urged Hutton to present himself as a candidate; and, though naturally diffident by habit, he travelled in a somewhat humble way from Newcastle to Woolwich, a distance of 300 miles (a long journey in those pre-railway times), to undergo the required examination. This was conducted by Colonel Henry Watson, the translator of Euler's "Treatise on the Construction of Ships;" Bishop Horsley, the editor of Newton's works; and Dr. Maskelyne, the Astronomer-Royal; but to none of them was Hutton known save by name, and many learned and influential men figured among the competitors, all of whom were examined separately, so that no one could avail himself of the information possessed by the others.

The examination, a very fair and impartial one, lasted a whole day, till late in the evening, and at its conclusion each candidate received a great many extremely difficult problems in the most abstruse parts of mathematical science to solve, and a week was given them to do so, when they were to appear at Woolwich again. Though by his humble circumstances Hutton was debarred the use of many books and other assistance which the other competitors could command, at the conclusion of the examination he triumphed over them all, and by the examiners was unanimously recommended to the Master-General and Board of Officers, and he was highly complimented "on account of the very able manner in which he had answered all their questions, and on account of his very extensive reading and acquirements."

The University of Edinburgh, where then the famous Dugald Stewart and Dr. Matthew Stewart were joint Professors of Mathematics, now conferred upon him the degree of LL.D.; he was elected a Fellow of the Royal Society, and in January, 1779, was appointed its foreign secretary, an office which he held till 1783.

The first edition of his "Compendious Measurer" was issued in 1784, and was the popular abridgment of his quarto treatise on "Mensuration;" this has gone through many editions since, and was generally adopted in all English schools, the elaborate demonstrations being omitted, while the rules, examples, and applications were retained.

In 1785 he produced a more profound and copious work, entitled "Mathematical Tables," containing hyperbolic, common, and logistic logarithms, together with sines, tangents, secants, and versed sines, both natural and logarithmic. To these were added many tables useful in mathematical calculations. This work, a thick royal octavo, was occasioned by the extreme inaccuracy of the logarithmic tables of Sherwin and Gardiner, and he introduced many striking improvements in the resolution of plane and spherical triangles; but the most valuable portion of it is the extensive and learned introduction which he prefixed to the tables. It contains a fair and impartial history of early trigonometrical writings and tables, natural and logarithmic; and the inventions and improvements are clearly traced, and assigned to their proper authors. The peculiarities of John Napier, of Merchiston (original inventor of the logarithms), of Briggs, of Kepler, Gregory, Mercator, and Newton, are carefully discerned, and an immense amount of labour and deep reading displayed.

In 1786 he issued a quarto volume of "Tracts, Mathematical and Philosophical," which proved of great value alike to the man of science and the mechanic; and in the following year he began the preparation of his "Mathematical and Philosophical Dictionary." After nine years of labour, it appeared in 1796, in two great quarto volumes, and its value was at once acknowledged by the British public. Though chiefly compilation, it contained much that was alike new and original, and exhibited great patience, research, and impartiality, with considerable historical disquisition, particularly in the elaborate memoir of algebra. Of the most eminent mathematicians and philosophers he gives short biographical sketches, which are often spirited, and always truthful. It was universally declared to be "a work which the student of mathematics and of natural philosophy may consult with pleasure, and always with considerable advantage."

His "Course of Mathematics for the use of the Cadets in the Royal Military Academy" appeared in two octavo volumes in 1798, and has since gone through many editions. To this a third volume, written in conjunction with his friend Dr. Gregory, was issued in 1811. From 1803 to 1809 he had been employed, in conjunction with Drs. Pearson and Shaw, in preparing an "Abridgment of the Philosophical Transactions of the Royal Society of London, from the Commencement, in 1665, to the End of the Last Century," a laborious and most important work, for his share in the execution of which he received £6,000. The "Abridgment" extended to eighteen thick quarto volumes, and was published in monthly parts, four of which constituted a volume.

After having filled with honour and popularity the office of Professor at Woolwich for thirty-four years, in the summer of 1807 he felt himself compelled to resign it, and retire from active life, having suffered much from a pulmonary complaint during the preceding winter and spring; but on his retirement the Board of Ordnance assigned for his past services, and as a testimony of regard, a pension of £500 per annum; and as he had previously amassed a handsome fortune by the profits of his literary and scientific exertions, he fixed his abode in London. In retirement his pen was never idle, but was constantly employed in the preparation of learned papers. Thus, five years after leaving Woolwich, he published his "Tracts on Mathematical and Philosophical Subjects," comprising, among numerous important articles, the theory of bridges, with several plans of recent improvement; also the results of numerous experiments on the force of gunpowder, with applications on the modern practice of artillery.

With many corrections and improvements, these volumes contain several of his detached essays and tracts previously

enumerated, together with the "History of the Writings and Investigations in Trigonometry and Logarithms," as published in the introduction to his "Mathematical Tables," and the "History of the Discoveries and Inventions in Algebra," which was first published under the word *Algebra* in his quarto dictionary. Most of the "Tracts," however, were new; among these were a clear and methodical narration of his interesting experiments in gunnery and projectiles.

The extraordinary and marked omission of Hutton's name by the Marquis Laplace, when speaking of the determination of the mean density of the earth, led to some correspondence between him and that learned French philosopher, in the years 1819 and 1820, for Hutton's feelings were undoubtedly wounded. His letter, which was published in the "Philosophical Magazine" of February, and in the "Journal de Physique" of April, 1820, remained unanswered for many months; but ultimately, in the "Connaissance des Temps," the marquis did ample justice to the learned Englishman, after he had described the nature and difficulty of computation relative to the earth's density, by adding, "All this was executed in the most satisfactory manner by Dr. Hutton, an illustrious mathematician, to whom the abstruse sciences are indebted for numerous other important researches."

A severe cold which he caught in 1822, by some unavoidable exposure, ended in a pulmonary complaint, which made speedy inroads on his constitution. His physical strength declined rapidly, and in his actions, conversations, and letters he showed a knowledge that his latter end was drawing nigh. Till near his death he yet retained the entire possession of his powers and all his fine perceptive qualities, and was able to go up and down stairs.

"On Friday, the 24th of January, 1823, only three days before the termination of his life," wrote his friend and successor, Dr. Olinthus Gregory, "I visited him, at his own request, in consequence of a communication which he had received from the Bridge House Committee, relative to the proposed new bridge in place of London Bridge. He could then see to read writing of the usual size without spectacles, and heard very well all that I said, on my aiming at a rather slow and distinct enunciation. His respiration was difficult, as it had been for some time; but on the whole I thought him better than when I had seen him a week before. Our chief conversation was on the subject of his letter from the City. He expatiated with his usual perspicuity and accuracy upon the theory of arcuation, the relative advantages and disadvantages of different curves selected for the intrados, the most judicious construction of centreing, etc. He then passed to the history of the erection of Blackfriars Bridge, sketched briefly the principles developed on that occasion by Mr. Simpson, his predecessor at Woolwich, and alluded to the scientific qualifications of Mr. Robert Mylne, the architect of that edifice—for which his designs were chosen before those of twenty other competitors, from their great superiority in the mode of centreing—but the effort greatly exhausted him, and compelled me to relinquish my intention of conversing with him on another topic. He entreated me to visit him that day week, and I most cheerfully assented, hoping the interview would have its peculiar interest."

Before "that day week" all was over, and the great mathematician had solved the problem of Time and Eternity; for on Saturday he became worse, on Sunday worse still. He sank into a comatose state as evening drew on, and expired at four o'clock on the morning of Monday, the 27th of January, 1823.

SANITARY ENGINEERING.—I.

GAS: ITS MANUFACTURE BY PUBLIC COMPANIES.

By W. T. Piper.

The first records that we have of the utilisation of coal-gas for lighting purposes date from about the middle of the seventeenth century; before that time there are many legends, as we may call them, of the rising of inflammable gas from the earth. The sacred fires in the East, and in some parts of Europe, doubtless drew their supplies from this source; and, curiously enough, the Chinese claim the honour of having used what may be termed natural gas for illuminating purposes many centuries ago. About the middle of the seventeenth century, some papers were read before the Royal Society upon the discovery of natural gas in Lancashire; and about the year 1800, or a little earlier, some of the more scientific and enterprising firms of the day had adopted "gas" as the ordinary means of lighting their workshops and factories. Of course, they made it themselves, as no public companies were in existence, and we may mention as an instance the factory of Messrs. Boulton and Watt, at Soho.

The first Act of Parliament creating a chartered company was passed in 1810, and in 1813 Westminster Bridge was lighted with gas. Illuminating gas for commercial purposes has been made from coal, rosin, oil, peat, and wood, with varying results as to economy and efficiency; but, as far as the present manufacture is concerned, *coal-gas* is the only source of supply, and it is to some explanation of the methods employed that the present paper is devoted.

The simple principle upon which all gas-lighting is founded is the exposure of coal to heat sufficient to produce combustion, in air-tight vessels—*i.e.*, to decompose the coal by heat, without the admission of the external air. The volatile portions have an outlet provided for them, which conduct them to receptacles for future use, and the solid matter remaining (coke) is not without its commercial value. Chemically, all the materials from which gas is made consist of carbon, hydrogen, and oxygen, in various proportions; and we may take it that the greater the per-centage of hydrogen the greater the illuminating power of the gas evolved. Cannel coal is, for this reason, the parent of a gas of much higher illuminating power than ordinary Newcastle coal, though, of course, the difference of price renders it comparatively expensive; while gas made from oil, especially some of the recently discovered hydro-carbons, has still greater brilliancy. This particular branch of the manufacture, however, may be considered almost in its infancy, and has not yet been adopted by any public company to such an extent as to warrant notice at the moment.

The first portion of the process, then, is to submit coal to the action of heat in an air-tight vessel, commonly called a "retort." These are made of various forms and various materials—wrought iron, cast iron, and earthenware—each having its peculiar characteristics as thus employed. Wrought iron, at high temperatures, undergoes rapid oxidation, as does cast iron, though possibly in a less degree, the latter being far more liable to fracture; earthenware, while perfectly free from oxidation, not being so good a conductor as the other materials.

The usual forms of the retort are circular, oval, or bean-shaped, but the form now in most common use may be described as the D form, the lower side being slightly curved upwards. 18 inches wide and 12 inches high, or perhaps rather larger, may be taken as an ordinary working dimension, and from 7 feet to 10 feet long, according to circumstances. A group of these retorts, from five to six in number, or more, as the case may be, are set in a furnace, and filled with coal from the end, and as soon as they are charged a gas-tight lid is screwed on the front of each. From the top of the front end of each retort rises what is technically called the stand-pipe—*i.e.*, the pipe through which the volatile products of combustion, *i.e.*, what may be called the crude gas—arise.

Many other forms of retort have been used. Some, in the North, have been constructed of wrought iron, with cast-iron bottoms, 4 feet or more wide and 1½ feet high, working off a ton of coals in about twenty-four hours. Stourbridge clay is now very largely used for the purpose, of course, in much greater thickness of material than either wrought or cast iron. To show, however, that it is specially applicable, we may mention that retorts have been made of it 10 feet long and 3 feet wide. We believe that it is gradually superseding the other materials for general use.

The arrangement and grouping of these retorts varies, of course, almost *ad infinitum* with the extent of the works of which they form part, and with the fancy of the engineers by whom they are designed.

But now to proceed. The retorts being charged and in working, what is the quality of the gas delivered by the stand-pipes? This, of course, varies also with the quality of the coal employed, and the temperature to which the retort is subjected. The higher the temperature the more volatile the product, and the larger the solid remnant; while too low a temperature, though leaving less residue, develops a large amount of an intermediate

and comparatively useless material, viz., tar; and it is to hit the exact medium between these points that the attention of the engineer is directed, as that is the most profitable gas that has the largest illuminating power. The gas evolved at too great a temperature approaches somewhat in its proportions to the natural sulphuretted hydrogen, which burns with considerable heat, but with little light; and therefore the main object is to release from the retort the gas the moment it escapes from the coal, before it is subjected to the further heat which would reduce its illuminating power.

We will suppose, however, this result to be successfully obtained, and that the gas in the stand-pipe is as good as can be made. It is not yet fit for use, as it contains vapour of naphtha, and tar, some steam, and compounds of ammonia, with other impurities, which, if it were sent forward at once for use, would condense in the pipes and interfere with the supply, or create an offensive smell in the process of combustion. This is specially the case when sulphuretted hydrogen is present, as is often the case; while when carbonic acid enters into the composition of the gas its lighting power is much reduced. The next process is as under.

The stand-pipes above described are generally conducted into a cylindrical receiver, into which their ends are reversed, and the condensation of tar and other matter, viz., coal-oil, is allowed to fill this receiver above the level of the ends of pipes thus introduced. When not at work they are thus hermetically sealed, and it therefore becomes possible to draw the charge of any particular retort without interfering with the others. From this receiver there is an overflow pipe to the tar cistern, so that the contents are always kept at a certain level. The next point is to reduce the temperature of the gas, which at this point of course is high, to something not much exceeding the external air. This is done by passing it through a refrigerator, or condenser; and in the course of this process it deposits all those elements which it could not retain in suspension at the ordinary temperature of the atmosphere. Sometimes currents of cold air only are employed, and sometimes a circulation of cold water through what may be called the double jacket of the condenser, which takes various forms in the hands of different engineers; the result, however, being in all cases the same—that the products of condensation thus deposited are led away and deposited in the tar cistern; and the gas, thus reduced to about the ordinary atmospheric temperature, has next to be subjected to the action of the purifier, which has to remove whatever sulphuretted hydrogen and carbonic acid remain in excess. Lime, either wet, in the form of milk of lime, or else dry, is the material that has been up to this time most usually employed, but now some forms of oxides are coming into use, and the quantity of lime is regulated by the quality of the gas. Supposing the per-centage of impurity to be eliminated is 5 per cent., 15 pounds of lime to the 1,000 cubic feet of gas is considered to be about the proper proportion, and, of course, the various calculations as to bulk, etc., follow from the size of the works.

There are various tests for ascertaining the purity of the gas after it has passed through this process, into which we shall go further in detail in future papers. The purifier is, in some cases, a cylindrical iron vessel, so arranged that the milk of lime is continually stirred by machinery provided for the purpose, and when it has answered its purpose—*i.e.*, when too foul for further use—there is the necessary provision for the removal of the foul and substitution of a fresh material.

Before, however, the gas enters the purifier, it has to pass the exhauster, an apparatus invented for the purpose of relieving the reverse pressure exerted upon the retorts by the passage of the gas through the cylindrical receiver, or hydraulic main, and other portions of the apparatus. The means are merely mechanical, consisting of various applications of valves, kept constantly in motion by steam-power. This has the effect of reducing leakage in the retorts, if there is any flaw, and of producing a more favourable condition of combustion; as it has been ascertained that if subjected to heat under pressure the illuminating power of the gas in process of evolution is much diminished.

Another method of purifying is by dry lime, the gas being passed through a series of sieves upon which it is spread; and another process has been patented by which a sort of Archimedian screw is kept constantly revolving in the lime liquid, and the gas and milk of lime being far more thoroughly mixed than by either of the previously described methods, a more perfect result is obtained.

The gas being thus made, cooled, and purified, it is necessary to store it, to provide for the necessities of consumption, so that it can be distributed as required at an equable pressure; and for this purpose are constructed the large circular gas-holders, popularly and erroneously called gasometers, which are the familiar and distinguishing feature of all large gas-works. These are constructed of wrought iron, and may be compared in form to an inverted tumbler, as they must be invariably provided with a tank of water, into which they subside when out of use. Their size is in proportion to the gas required to be consumed within a certain time, and there should always be a considerable margin, in case of any accident to the retorts or other portions of the apparatus. The action is as under. They are suspended and confined in their position by columns, generally of cast iron, on which are pulleys, with chains attached, to which are heavy counterbalanced weights. When empty they are down at the level of the water, or nearly so; as they fill, the pressure of the gas gradually lifts them to the extent of their construction. The cisterns in which they work are sometimes built of brickwork, and sometimes of masonry; and sometimes, when the situation of the works renders this class of building difficult, a double cistern of wrought iron or cast-iron is substituted, between the inner and outer skin of which the gas-holder travels up and down.

A recent improvement in gas-holders is the introduction of the telescopic principle. If made in a single cistern and piece, great space is required on the plan, in proportion to the quantity of gas stored; but by the introduction of the telescopic principle, three times the storage can be obtained upon the same extent of ground, the three cisterns, one above the other, subsiding when empty into the height of a single one of the three; while when full, with gas-tight joints at the junction, they are drawn out to their full height like the joints of a telescope. It is rarely necessary to change the water in a gasholder, because its surface soon becomes covered with a stratum of coal-oil, which prevents evaporation to a great extent.

Having thus described the manufacture and storage of gas, we now proceed to the question of its distribution by means of gas-mains; and, of course, the first question is the quantity of gas required to be delivered within a given time. This has frequently been made the subject of experiment, and the results have been tabulated: we will, however, quote a figure or two, showing the results which have been thus ascertained. A pipe of about 4½ inches in diameter, and 1,000 feet long, will deliver 2,000 cubic feet of gas per hour, while one of 9 inches, or rather more, 2,000 feet long, will deliver 6,000 feet per hour; the formula being, that under similar circumstances of pressure, the powers of transmission of different pipes are directly in proportion to the squares of their diameters, and inversely as the square root of their length.

Cast-iron socket-pipes are generally used for the principal mains, the joints formed with a luting of clay run with lead, driven home by a mallet and chisel. The lesser pipes for house supply are mostly drawn pipes of wrought iron, while the smallest pipes—viz., those which serve only single burners—are usually of tin or pipe metal. Into the detailed description of various kinds of burners, gas meters proper—*i.e.*, machines for measuring the quantity of gas burnt—gas regulators, for controlling the pressure, and other similar inventions, we shall enter in some future papers. The industrial aspect of the question is a most important one; it is no exaggeration to say that hundreds of millions of pounds are at the moment invested in plant for the manufacture of coal-gas. And to give an idea of the extent to which enterprise is developing the system in this country alone, we may mention that in the session of 1870, there were forty gas bills introduced into Parliament, authorising an additional expenditure in that year only of more than £3,000,000, while in the following session (1871) the number of similar bills increased to forty-five.

Such is the importance of the manufacture, of which a rough outline only has been given, but which is sufficient to show the method adopted in its manufacture in retorts at the gas-works, its storage in gas-holders, and its distribution for general consumption through pipes of various sizes.

MINING AND QUARRYING.—IV.

BY GEORGE GLADSTONE, F.C.S.

COAL.

WINNING—BY LEVEL—BY SINKING—CHOICE OF LOCALITY—SINKING THE SHAFT—FORM AND FITTINGS—UNDERGROUND PLAN OF MINE—POST AND STALL, AND LONG-WALL SYSTEMS.

THE mode of getting at the coal depends upon the nature of the ground, and the level at which the workable seams occur. The simplest case is where the country is hilly, and the seam to be worked extends above the level of the valley. It can then be reached by driving a horizontal gallery or small tunnel from the hill-side until it cuts the seam. A miner, however, would not adopt a dead level, but would make it rise gently from the entrance, so that the water should not collect in the workings. Thus the expense of pumping would be saved. A tramway laid along the gallery would connect the productive part of the mine with the outside world.

The majority of mines are, however, below the surface, and the coal can only be reached by sinking. In this case the excavation, instead of being horizontal, is perpendicular, and is called a *shaft*. The sinking of a shaft is often a tedious and very expensive operation, and before commencing it has to be well considered where to place it. A deep shaft, including engine-power, has been known to cost £100,000, and to occupy ten years to complete.

The shaft in a deep mine being the centre from which all the subsequent operations ramify, it should be put in the most convenient situation for the underground workings. If the ground is broken by faults, it should be removed as far as possible from them; and as a general rule it should be towards the dip and not the outcrop, because the pit should drain to the bottom of the shaft, and the coal-laden trucks have to be brought to the same point.

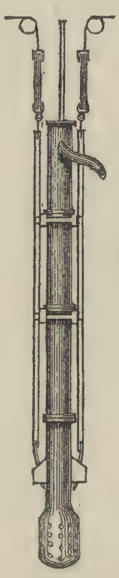


Fig. 8.

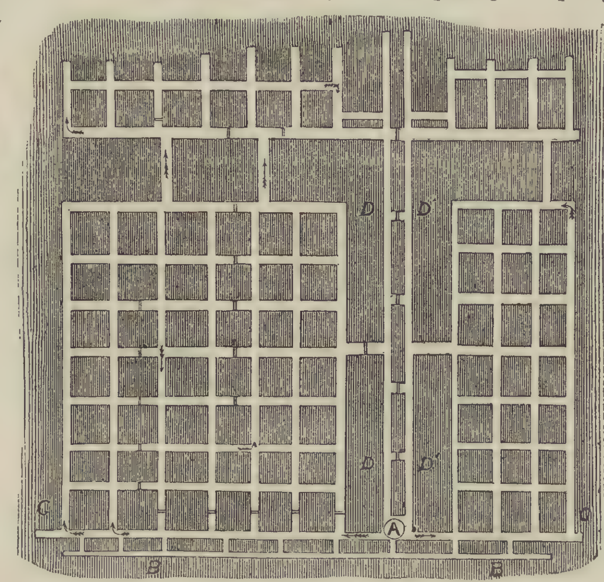


Fig. 9.

The spot being determined, we will suppose a first-class deep pit to be opened up. In order to economise expense, the one shaft must serve for pumping, ventilation, the ascent and descent of the miners, and the bringing of the coal to the pit's mouth; though in very extensive workings a second shaft would have to be sunk.

The best form of shaft is the circular, that being the strongest in proportion to the quantity of material employed. It is usually divided by brattices into four equal portions. One of these is devoted to the pumps, a second to ventilation, and the other two to the ascending and descending coal buckets. The diameter of such a shaft is usually about fifteen feet.

The principal difficulties connected with the sinking do not consist in the hardness of the rock which has to be excavated, because that is a mere question of labour and the use of gunpowder. When very hard, several holes are drilled near the outer part of the circle and charged; the workmen can then come up out of the way of danger, and all the charges be fired simultaneously by an electric battery. Water is the article which gives the workmen most trouble. They are sure to cut feeders of water, especially at the junction of different layers of rock, and often beds of very wet sand, which are the most troublesome of all. To guard against these eventualities, it is always necessary to have pumping power ready, and in piercing through a new district powerful engines for this purpose should be provided, as it is better to have a waste of power than have the workings drowned through inability to keep the water under.

The first portion of the shaft, consisting of loose or broken materials, and liable to contain at times a good deal of water, generally needs to be "tubbed." The process of tubbing consists of lining all the sides of the shaft with thick staves of oak, well wedged together in a strong frame, so as to form water-tight sides. Iron has of late years been substituted for wood with great advantage. Cast-iron tubbing is made in arcs of a circle corresponding in radius with that of the shaft, having the flanges by which they are fastened together on the outside. As soon as any wet and soft stratum is approached, the segments are fixed together round the sides of the shaft, and the upper part loaded with heavy weights, so that it sinks down of its own accord as the labourers dig out the mud or sand from the midst. Any number of rows of these segments can be fastened one upon another according to the depth required.

During the process of sinking the pumps are so arranged that they can be let down gradually as the work proceeds. They hang upon tackle passing over pulleys, and descend by their own weight as fast as the excavations will allow; a flexible hose is attached to the spout in order to convey the water to the cistern. The arrangement will readily be understood by reference to Fig. 8.

At every twenty-five to thirty fathoms a cistern is made in an excavation of the rock, and for that portion a permanent pump is then provided. In some cases lift-pumps, and in others force-pumps are used. They are in almost constant requisition as long as the colliery lasts, and in old workings, where a large area has been excavated, they are kept going night and day, as the amount of drainage increases steadily in proportion as the colliery is opened out.

Having thus sunk the shaft down to the seam which it is intended to work, the coal is said to be *won*. The plan of working the mine has now to be laid out.

This has to be regulated by several considerations, the object being to remove as much of the coal as possible, but in such a manner as to secure a thorough ventilation of the mine, and the safety of the miner from the falling in of the roof.

The shaft A, as shown in Fig. 9, is sunk near the dip-head, so that as the workings are extended the water shall drain down to that point; and in order to collect it, a dip-head level, B B, is cut in the first instance. The first working gallery, C C, is then made, usually parallel to the other, extending from the pit bottom right and left. From this the galleries run up towards the outcrop in parallel lines, which, as they advance, are connected by others at right angles, so that the mine assumes the appearance of an underground city laid out upon a rectangular plan, the blocks of houses being represented by the unworked coal. No uniform system can, however, be adopted, as the plan of operations has to be modified according to the special circumstances of every mine. The diagram will serve as a specimen of what is called *panel-working*, with post and stall, from a single shaft, a plan rather common in the Newcastle district.

All workings may be considered as modifications of the *post and stall*, or of the *long-wall* system. The latter is more generally adopted in the midland counties.

We will take post and stall first. It has other names, such

as *board and pillar*, or in Scotland *stoop and room*. The pillars or blocks of unwrought coal support the roof, and the galleries between them being comparatively narrow, a system of ventilation can be arranged by closing up some of them with doors, which could not be accomplished were the mine worked irregularly, and with large open spaces. Upon the panel system the whole colliery is laid out in panels, of which one complete one and parts of three others are shown in the diagram, with thick walls of coal between each, perforated only here and there, just sufficiently for communication and ventilation. The whole mine being opened up in this way, the pitmen proceed to work out the pillars completely, beginning with those in the furthest corners, where the pressure from above is most divided. While these are being removed, pit-props of timber have to be inserted to support the roof. As each pillar is cleared the men draw out the props, beginning with the most distant one, and allow the roof to fall in, filling up the space with broken stone, which is then termed a *goaf*. One by one the pillars disappear, and the goaf extends, until the whole of the coal has been worked out of the panel, the panel walls in their turn being worked away as far as possible, so that very little coal need be eventually lost.

Upon the old system the passages used to be made much wider, and the pillars only large enough to support the roof; but that arrangement has several disadvantages. The whole of the weight being thus left to rest upon a small area, the pillars were sometimes forced down into the floor, which would bulge upwards and form a *creep*; or if the roof were tender, it would be apt to break away and fill up the passage, which would be a *sit*. These are both very difficult to cure, and are very objectionable, as they not only prevent the passage of the workmen, but also derange the systems of drainage and ventilation.

The two galleries D D, D′ D′, which run directly from the shaft towards the crop, are termed the *winning headway*, which is always carried rather in advance of the other workings. It is the main channel of communication, by which the coal from the more distant parts is brought to the pit bottom, and which also brings the heated air, after having made its circuit through the workings, to the upcast shaft. This headway is, of course, kept in effective condition throughout the progress of the mine, and is the last part that would be touched.

The principles upon which the ventilation of such a colliery would be conducted are indicated by the arrows, the passages being closed by doors where the cross lines occur. There is no difficulty in establishing a current of air in a deep pit, because the temperature at the bottom of the shaft will be naturally much higher than at the top, and the shaft being divided into segments, the hot air is made to pass constantly up one of them (called the upcast shaft) by having a furnace at the pit bottom connected with that segment, while the fresh air from above coming down the downcast shaft, is conducted at once into the galleries.

Upon the long-wall system, the dip-head level, the winning out walls right and left, and the winning headway must first be made as before; and then commencing at some little distance from the shaft, long galleries would be driven parallel to one another. The miner then proceeds at once to clear out the coal between each gallery, allowing the roof to fall in as he proceeds, except wherever it may be necessary to keep a passage open for the sake of ventilation. The mine thus presents a series of long walls, and the pitman holes or undermines the coal with his pick as deep as he can reach right along the line of the wall, when the pressure from above—there being no support on the other side—readily breaks the coal up; or if it should prove too firm it is broken down with wedges. On this plan, therefore, the miner is constantly working with a falling roof almost immediately behind him; but upon the whole it is not found to be more dangerous than the other system, while it is rather more economical of coal. If the roof should prove to be tender, it is shored up with props to a sufficient distance to protect the men, or they make a supporting wall of the blocks of stone which can be got out of the goaf. Those passages which require to be retained are permanently walled up with stone, so as to keep the roof entire. In this mode of working the air-passages are frequently made to cross, one being carried under the other through a little tunnel. By the long-wall method the workings are carried from the shaft outwards, the coal-seam being thoroughly cleared as the work proceeds; but as it is of the greatest importance that the shaft should not be liable to the least disturbance, which might easily stop the colliery altogether, and endanger the lives of the men, a solid mass of coal is always left untouched immediately round the pit bottom.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XII.—GENERAL DUDD DUDLEY.

BY JAMES GRANT

THIS celebrated Cavalier officer and faithful adherent of Charles the First, the inventor of iron-smelting by *pit-coal*, was born during the reign of Queen Elizabeth, in 1599.

Prior to his time, iron had been chiefly imported by the Steelyard Company of foreign merchants in Upper Thames Street; the great coal resources of England were yet undeveloped; her old forests of the Saxon times were disappearing fast; and the severe restrictions enforced by the Legislature against the use of wood in iron-smelting had the effect of nearly extinguishing the manufacture, as the old iron-smelters maintained that it was impracticable to reduce the ore by any other process than by means of charcoal-wood. Sturtevant, a German skilled in mining operations, suggested the adoption of earth-coal and brush-fuel in a "Treatise" which he wrote; but Dudd Dudley was the first Englishman who, on finding that his furnaces were failing by the want of wood, adopted pit-coal in its place, and in spite of all local prejudice.

This speculator was the natural son of Edward Lord Dudley (of Dudley Castle in Worcestershire) and of Elizabeth Tomlinson; he was one of eleven children by the same mother. All these were educated with care by Lord Dudley, who bestowed Netherton Hall upon the eldest brother of Dudd, while their sisters were all married well among the best families in the county. After completing his studies at Balliol College, Oxford, Dudd, who was a special favourite with his father the earl, was sent by him in 1619 to take charge of two forges and an iron furnace, possessed by him in the chase of Pensnet, Worcestershire. Finding wood scarce, he immediately employed pit-coal as a substitute; and so successful was the result of the first essay, that he was resolved to persevere in its use. Though the portion produced by the new process was somewhat little—being about three tons per week from each furnace—he confidently expected that increased experience would enable him to double the quantity; "and at all events, he had succeeded in proving the practicability of smelting iron with fuel made from pit-coal, which many before him had tried in vain."

Through his father the earl, who was then in London, he sought for and obtained from King James a patent for his invention; and it was issued in Lord Dudley's own name, on the 22nd of February, 1620. In addition to his manufactory for iron at Pensnet, Dudd Dudley now erected another at Cradley in Somersetshire; and a year after the issue of the patent, he was able to send, in obedience to the king's command, a great quantity of this new iron to the Tower of London, where its qualities were fully tested for various purposes. Dudley was now on the high way to fortune, and there was every prospect of the new method of smelting becoming fairly established as a staple manufacture, when calamities none could foresee fell upon the inventor, to the great joy of many rival iron-smelters, who either envied him the possession of his patent, or adhered obstinately to the use of charcoal.

On Mayday a great flood swept away his works at Cradley, and damaged all the district of Stourbridge, where the river rose so high that all the lower portion of the town was submerged by water, and the hostile iron-masters now hoped "that there was an end for ever of Dudley's pit-coal iron." However, he soon repaired his forges and furnaces, and had them all in working order for supplying the market. His rivals now endeavoured to influence the king against him; hence he was again ordered to send to the Tower a fresh supply of his iron for peculiar testing; and on proof, it was found fit for the manufacture of muskets, carbines, ship-bolts, and so thoroughly excellent in quality, that his enemies were silenced till the year 1624, when they made incredible exertions to have his patent abolished by a statute

which was passed in that year, for sweeping away old monopolies; but all they could accomplish was a limitation of the said patent to fourteen, instead of thirty-one years. Dudley now poured vast quantities of iron into the market yearly, and also manufactured all manner of cast-metal ware, brewing cisterns, pots, pans, mortars, and weights; but notwithstanding his complete temporary success, more misfortunes of a serious nature were in store for him.

A general combination of his rivals, who succeeded in fastening vexatious law-suits upon him, drove him in succession from his works at Cradley, from others he had erected at Himley in Staffordshire, and also from a large new furnace he erected near Sedgeley, and had provided with unusually large bellows. The latter works were barely completed, when a mob of rioters, instigated by the charcoal-smelters, cut the great bellows to pieces, tore down the stone furnace, and destroyed the machinery, laying the whole place in hopeless ruin, and from that day Dudley had no peace. His creditors swooped down upon him, and he was sent to London a prisoner, and detained in the Comptoir for debt, leaving the exulting charcoal-smelters in full possession of the field.

Charles I. was now upon the throne, and that humane king took pity on the unfortunate inventor whose deep-laid ingenuity and persevering industry had availed him so little; and on Dudley's release from prison he granted him a renewal of his patent in 1638, three other persons—a Sir George Horsey, David Ramsay (a Scot), and Roger Foulke—joining him as partners, and providing the requisite capital for smelting on an extended scale; but barely was the patent secured when the great Civil War broke out, and all over the land the plough and the hammer were relinquished for the sword and musket. Dudd Dudley now attached himself to the fortunes of his patron the king. In the year prior to these troubles he had accompanied, in some official capacity, the Marquis of Hamilton, who was sent by Charles as Lord High Commissioner to the Parliament and Church of Scotland; and from Edinburgh he would seem to have seen a portion of that then *terra incognita*, the Highlands, and also to have visited a Sir James Hope at the Leadhills near Glengower, a wild and desolate region still, but where lead mines are yet worked with success and profit.

In 1639 Dudley accompanied Charles in his rash invasion of Scotland, a movement which the Scots anticipated by entering England with 4,000 cavalry and 20,000 infantry under General Leslie. Dudley was present at the defeat of the king's troops at Newburnford on the Tyne, where Charles's royal standard was taken and many men killed on both sides.

In 1640 Dudley was appointed Surveyor of the Armoury; but being too poor to pay the patent fees, another was appointed in his place; yet he remained staunch to Charles; and when the latter left London, after the fall of his evil counsellors Laud and Strafford, he accompanied him. He was with him before Hull, the first town in England which closed its gates against the ill-fated monarch; he was at Nottingham when the royal standard was raised, and at Coventry when the people fired on the king's troops from its fortifications, which then consisted of strong walls and twenty-six towers; he was present at the battle of Edgehill, the first regular action between Charles and the Parliament in 1642, and in all the other engagements of that unhappy year.

After serving as major in Sir Francis Worsley's regiment, in 1643, he acted as military engineer, and after strengthening the fortifications of Worcester and Stafford, where the old castle of the Conqueror's time was garrisoned by the Royalists, he furnished them with ordnance. After the storming of Lichfield he was made colonel of dragoons, a species of force which then, and for long after, fought either on horseback or foot; and in this capacity he escorted Queen Henrietta to Oxford, where, in 1644, the king summoned such members of both houses as were devoted to his interests. Dudley afterwards served at the siege of Gloucester, which was then defended by a strong wall, afterwards demolished by Charles II., and with Sir George Lisle he led the vanguard at Newbury. Lisle, the son of a London bookseller, was distinguished for his bravery, and was knighted by the king on the field. Dudley next served at Newport under the famous Sir Charles Lucas, and the year 1645 saw him appointed general of Prince Maurice's train of artillery; and in this capacity, true to his old smelting instincts, the iron counties being at that time in the hands of the cavaliers, he turned his practical experience to account by the forging of small drakes (*i.e.* 6-pounder field guns) of bar-iron for the king's service.

When Goring raised his standard in Essex, and was besieged in Colchester, Dudley endeavoured to join him at the head of 200 horse, raised mostly at his own expense. These, while posted in a wood near Madeley, were attacked by a body of Cromwellians, and were all killed, dispersed, or taken prisoners. Dudley, two majors (Elliot and Harcourt), a captain, and a cornet were taken, stripped almost naked, and conveyed with every indignity to Worcester, where they were thrown into the common prison. Harcourt was severely scorched by gun-matches. Dudley, who had been wounded in the leg, and Elliot effected their escape, but were hotly pursued. Travelling only in the night, and hiding in trees by day, they reached London, after proceeding 111 miles on foot, only to be re-taken, and sentenced by the Committee of Insurrection to be imprisoned in the Gatehouse of Westminster, from whence they were to be taken on a certain day, and shot to death with other luckless Royalists then in the hands of Oliver Cromwell.

Ere this fatal day came Dudley was again free. During the time of sermon on Monday, the 20th of August, 1648, Dudley, Sir Henry Bates, and nine other captive cavaliers, succeeded in suddenly overpowering their warder, in breaking out of prison and making for the open country, when they dispersed, each one to shift for himself. Dudley's wounded limb sorely impeded his progress, and he had to proceed on crutches, and of course while penniless, through Worcester and Gloucester to Bristol, on one occasion having to remain hidden for three weeks in a hay-mow.

The king beheaded, his adherents dispersed or in prison, Dudley's career as a soldier was over. The estate left him by the earl his father, a place called Green Lodge, valued at £200 per annum, had been transferred to a Cromwellian named Major Wildman; his house in Worcester had been seized, and his wife turned into the streets; his iron-works were destroyed; all the offices he had held under King Charles were gone; and he was now menaced by destitution and starvation on the highway.

Poor though he was, he was still master of the secret process of smelting iron by pit-coal, and he lived on in the hope of one day turning it to account again. After the defeat of the Scottish Royalists at Worcester, the pursuit of their English brethren soon ceased, and Dudley, emerging from his lurking-place at Bristol, succeeded in inducing John Stone, a merchant, and Walter Stevens, a linendraper, both of that city, to join him as partners in a forge and furnace to be erected near it; but, unhappily, a quarrel ensued among them; the works were stopped; the concern was thrown into Chancery, and, of course, remained there hopelessly.

Major Wildman, a fighting preacher, had become possessor of Dudley's little estate, in the hope of extorting or discovering somehow his secret of iron-smelting; but in vain. He cut down all the timber, however, and demolished two mansions that were on it, and sold the materials.

At the Restoration in 1660 Dudley petitioned the king for a renewal of his patent, and for some compensation for the heavy losses he had sustained during the war. He failed to procure the former and also the latter, for Charles was besieged by similar petitions, and by applications of all kinds from England and from Scotland too. Undeterred by want of success, however, he petitioned again that he might receive his rank in the Ordnance, be appointed Master of the Charter House in Smithfield, or to any living which would support him, for he was in his sixty-first year, and all that he had undergone had sorely injured his health; and as a reward for his perseverance he obtained the office of Serjeant-at-arms.

A few years later, he succeeded in ousting Major Wildman from his estate in the country, and resuming there the process of iron-smelting. He restored his works at Cradley, and erected three great forges at Green Lodge. For many years more he continued to prosecute the manufacture of iron, till eventually he retired to the village of St. Helens in Worcestershire, where he died in 1685, in the eighty-fifth year of his age, and was buried within the walls of the parish church. So closed a long and stirring life.

"Dudley's invention of smelting iron with coke made of pit-coal was, like many others, born before its time," says the

author of "Industrial Biography;" "it was neither appreciated by the iron masters, nor by their workmen. All other schemes for smelting ore with any other fuel than charcoal made from wood were regarded with incredulity. As for Dudley's *Metalum Martis*, as it contained no specification, it revealed no secret; and when its author died, his secret, whatever it might be, died with him. Other improvements were doubtless necessary before the invention could be turned to useful account. Thus, until a more powerful blowing-furnace had been contrived, the production of pit-coal iron must necessarily have been limited. Dudley himself does not seem to have been able to make more on an average than five tons a week, and seven tons at the outside. Nor was the iron so good as that made by the charcoal; for it is admitted to have been especially liable to deterioration by the sulphurous fumes of the coal in the process of manufacture."

BUILDING CONSTRUCTION.—XVI.

ROOFS (*continued*).

THE following terms are constantly used in relation to roofs, and the explanation of them here will be found of service to the student:—

Wall-plates are pieces of timber laid on the wall in order to distribute the pressure of the roof equally, and to bind the walls together. Were it not for wall-plates, the tie-beams of a roof or the joists of a floor would rest on single bricks, whilst the spaces between the joists would not in any way assist in bearing the load. The wall-plate lying on the whole length of the wall, therefore, spreads the pressure over all the bricks, and the trusses, or joists, rest on a frame of timber.

Trusses are strong assemblages of timber, generally of a triangular form, serving to support the purlins on which the common rafters rest. They are disposed at equal distances, and are used when the expansion of the walls is too great to admit of common rafters alone, which would be in danger of being bent or broken by the weight of the covering, for want of some intermediate support.

They are variously constructed, according to the width of the building, the contour of the roof, and the circumstances of the walling below.

Tie.—Any piece of timber connected at its extremities to two others acted upon by opposite pressures, which have a tendency from each other, or to extend the tie as a rope or chain.

Straining-piece.—A piece of timber connected at its extremities to two others acted upon by opposite forces, which tend to press them together. The straining-piece, by being placed between them, serves to keep them apart, and, further, acts as an abutment for the external pressure.

Hence a tie and a straining-piece act in a manner exactly opposite to each other—the one draws the ends of two pieces of timber *together*, the other keeps them *apart*. A rope, chain, or iron rod could be used for the tie; but the straining-piece, which has to bear end pressure, must be always stiff and inflexible.

Principal rafters, or, as they are sometimes called, "principals," are the two pieces of timber which form the sides of a truss; their lower ends being mortised into the end of the tie-beam, or resting in an iron shoe, whilst their upper ends abut on and support the head of the king-post.

Purlins.—Horizontal pieces of timber resting upon the principal rafters, and at right angles to them; they pass from truss to truss, and across these again are laid the

Common rafters, which are pieces of timber of a smaller section, placed at equal distances across the purlins, parallel to the principal rafters. They support the boarding or battens to which the slating is fixed.

The *tie-beam* is the horizontal piece of timber which forms the base of the triangle or other figure of which the truss may consist. As already mentioned, it receives the ends of the principal rafters, and is strapped up to the king or queen posts. The tie-beam answers a twofold purpose—viz., that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the room below. In some cases it is found desirable not to place a tie-beam at the foot of the rafters, but to use it as a connecting link higher up, something like the horizontal line in the letter A; in this case it is called a *collar-beam*.

King-post.—This is an upright piece of timber in the middle of the truss. Its upper end acts as a key-stone of an arch, against which the principals abut, and, being thus supported, the tie-beam is strapped or bolted up to its lower end; and thus not only is sagging or sinking prevented, but abutments are formed for struts, which give support to the principals in points between the tie-beam and the king-post.

Queen-posts.—Upright pieces of timber, framed above into the principals, and supported by a straining-piece or strut, whilst to their lower ends the tie-beam is bolted or banded up at points between the wall-plates and the king-post. Some trusses are constructed without king-posts; queen-posts only being used.

Struts are oblique straining-pieces, framed below into the king or queen posts, and above into the principal rafters, which are supported by them; or sometimes they have their upper ends framed into beams which are too long to support themselves without bending. They are often called *braces*.

Puncheons are short transverse pieces of timber fixed between two others for supporting them equally. They are sometimes called *studs*.

Straining-beam.—A piece of timber placed between the queen-posts at the upper ends, in order to withstand the thrust of the principal rafters.

Straining-sill.—A piece of timber placed between the lower ends of two queen-posts, upon the tie-beam, in order to withstand the force of the braces, which are acted upon by the force of the covering.

Camber-beams.—These are horizontal pieces of timber, made sloping from the middle towards the ends on the upper edge. They are placed above the straining-beam in a truncated roof, for fixing the boarding on which the lead is laid. Their ends run three or four inches above the sloping plane of the common rafters, in order to form a roll for fixing the lead. This is shown in Fig. 154 in the next page, which is the roof-truss of the chapel of the Royal Hospital at Greenwich, constructed by Mr. S. Wyatt.

Auxiliary rafters are pieces of timber framed in the same vertical plane with the principal rafters, under and parallel to them, for giving additional support when the extent of the building requires their introduction. They are sometimes called *principal braces*, and sometimes *cushion rafters*.

Joggles.—The joints at the meeting of struts with king-posts, queen-posts, or principal rafters, or at the meeting of the rafters with king and queen posts. The best form is that which is at right angles to the length of the struts.

Cocking, or Cogging.—The particular manner of fixing the tie-beams to the wall-plates. One method is by dovetailing; the other is by notching the under side of the tie-beam, and cutting the wall-plate in the reverse form to fit it.

Ridge-tree.—A piece of timber fixed in the vertex of a roof, where the common rafters meet on each side of it. The upper edge of it is higher than the rafters, for the purpose of fixing the lead which goes over it to cover the ends of the slates in the upper course.

Straps.—Thin pieces of iron running across the junction of two or more parts of a truss or frame of carpentry, branching out from the intersection in the direction of the several pieces. They ought always to be double—viz., one on each side of the timbers, and their ends strongly bolted to each of the pieces.

The uses of these various parts will be illustrated in the subsequent examples; but it must be understood that though every one of them *may* be found in the same roof, it is not necessary that any complete roof should have them all. The introduction of many of them depends on the distance of the walls, the contour of the roof, the partitions below, the quantity of head-room wanted in the garrets, etc.

Fig. 154 is the truss employed in the roof of the chapel of the Royal Hospital at Greenwich, already alluded to.

It is constructed with two queen-posts, B B, and has two struts, C C, from the foot of the queen-posts to the straining-beam, D, and which abut against a second straining-piece, E, underneath the first. The tie-beam, A, is also further suspended from the straining-beam by an iron rod, H, which answers the purpose of a king-post.

The trusses are seven feet clear apart. The platform is

covered with lead, which is supported by horizontal beams 6 × 4 inches. The timbers of this are well disposed, and contain, perhaps, less wood than most roofs of the same dimensions.

The following are the scantlings of the various timbers, which are given to enable the student to work this example to a regular scale, and which should not be smaller than a quarter of an inch to the foot:—

	inches.
A, the tie-beam, 57 feet long, the span of the walls being 51 feet	14 × 12
B, queen-posts	9 × 12
C C′, braces or struts	9 × 7
D, straining-beam	10 × 7
E, straining-piece	6 × 7
F, principal rafters	10 × 7
G, camber-beam for platform	9 × 7
H, iron rod supporting tie-beam	2 × 2

It is scarcely necessary to remind the student that the tie-beam must be drawn first, then the queen-posts, the principal rafters, and the straining-beam; afterwards the struts and straining-piece; then follow the iron rod, the camber-beam, the purlins, and the covering.

Fig. 155 is the roof of St. Paul's, Covent Garden, London designed by Mr. Hardwick, and constructed by Mr. Wapshot, in the year 1796.

This roof, although of the same general construction as the chapel of the Royal Hospital at Greenwich, varies from it in several particulars.

There is a second pair of principals, H H, which are supported on the lower, F F, by studs, and the lower principals thus become only auxiliaries. The queen-posts, B B, are continued up to the principals, and a king-post, D, is carried from the apex to the straining-beam.

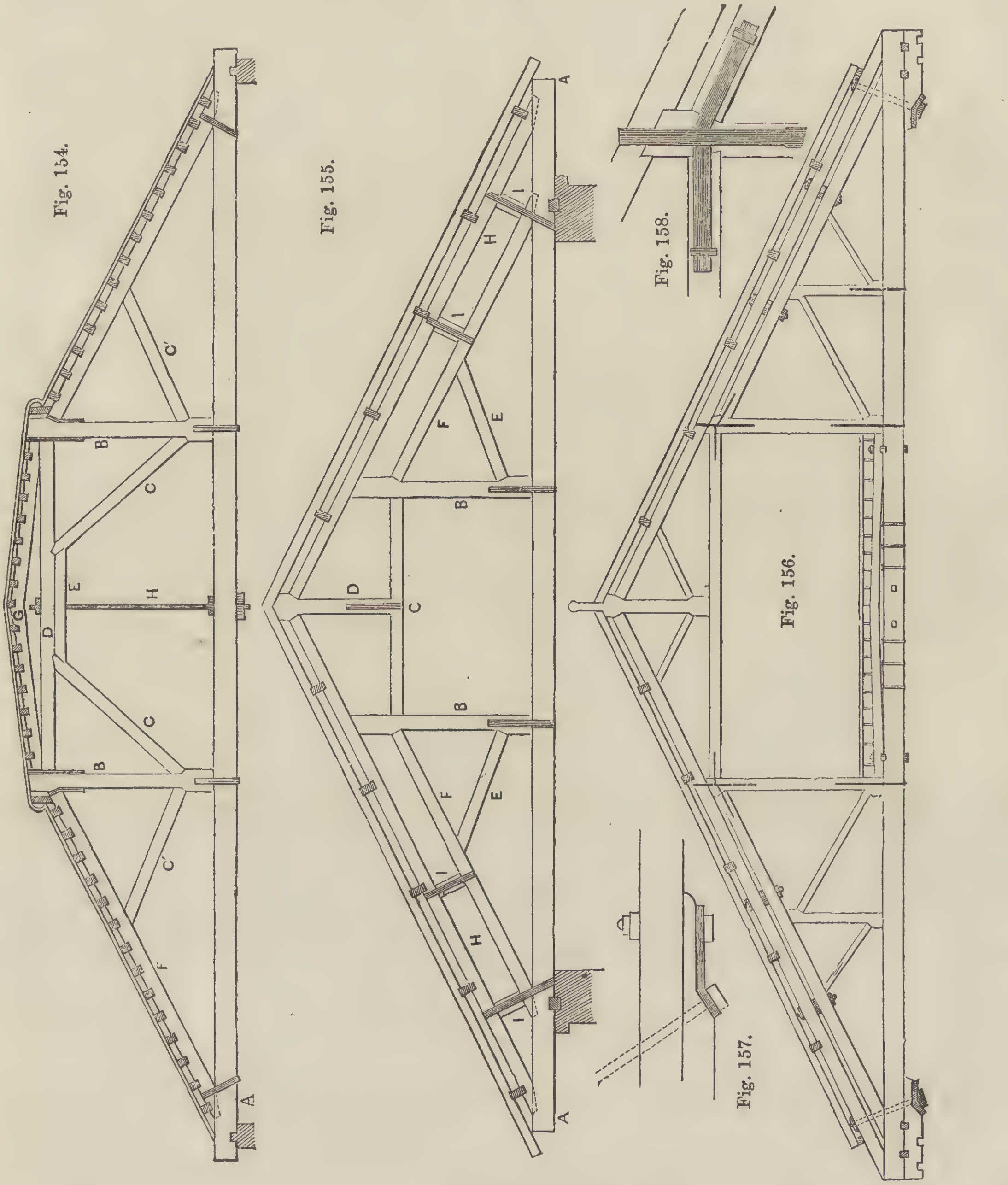


Fig. 154.

Fig. 155.

Fig. 156.

Fig. 157.

Fig. 158.

The following scantlings are given for the same reason as in the last case:—

	inches.
A, the tie-beam, spanning 50 feet 2 inches	16 × 12
B, queen-posts	9 × 8
C, straining-beam	10 × 8
D, king-post (14 inches at the joggle)	9 × 8
E, struts	9 × 8
F, auxiliary rafters at bottom	10 × $8\frac{1}{2}$
H, principal rafters at bottom	10 × $8\frac{1}{2}$
I, studs supporting the principals	8 × 8

It will be seen that this roof consists of an outer truss supported by an under one, the whole projecting seven feet beyond the walls.

Fig. 156 represents the present roof of Drury Lane Theatre, London. Here are both principals and auxiliary rafters, the tie-beam being suspended at two points from the former, and two from the latter, the two first queen-posts being the inner ones. These are kept apart by the straining-beam, against which they are pressed from the outer side by the auxiliary rafters. Struts are placed between the feet of the principal and the heads of the secondary queen-posts, and the bearing of the sub-rafters is still further reduced by a strut from the foot, and on the other side of the small queen-posts. The straining-beam is supported by a king-post, from the apex of the principals, which in their turn are supported by struts from the foot of the king-post, the other portion having a continuous bearing on the auxiliary rafters.

Fig. 157 shows how the timbers are joined and strapped at the top of the queen-posts, the whole being tightened up by iron wedges at the lower end of the iron strap, as already described in relation to king-posts.

Fig. 158 shows how the ends of tie-beams are strengthened by saddle-pieces, and how the principal and auxiliary rafters are inserted and bolted on to them. It will be observed that the heads of both the bolts pass through the same iron plate, which is bent at the oblique part of the saddle-piece, so that the head of the bolt may be at right angles to its length.

The method of drawing both the last figures is so precisely similar to the previous example, that no further instructions are necessary.

CIVIL ENGINEERING.—VII.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

CANALS.

THE Cromford canal, constructed by Jessop, and completed in 1793, offers some points of interest to the engineer. The width at the top is 26 feet, but in the Ripley tunnel it is contracted to 9 feet at the surface of the water, and from thence to the crown of the arch the height is 8 feet. The tunnel is 2,966 yards long, and thirty-three shafts were sunk in its construction, some of which are 210 feet deep. The cost of the work averaged £7 per lineal yard. An aqueduct bridge, 200 yards long and 30 feet high, having a span of 80 feet, conveys the canal over the Derwent. The supply reservoir over the Ripley tunnel has an area of 50 acres; it is 12 feet deep, and contains 2,800 locksfull of water. The embankment of the reservoir is 200 yards long, 156 feet wide at the base, and 12 feet wide at the top. The cost of cutting and wheeling the clay to form the reservoir was $3\frac{1}{2}$d. per yard cube, and for gravel $4\frac{1}{2}$d. The entire canal cost £80,000. The boats navigating it are 80 feet long, 7 feet 2 inches wide, and 3 feet 4 inches deep. They draw $2\frac{1}{2}$ feet of water when loaded with twenty-two tons, and only 9 inches when empty.

One of the more important canals in this country, before the development of the railway system, is the Ellesmere and Chester, connecting the Severn, Dee, and Mersey. The entire length is 103 miles. The most important feature of this canal is the aqueduct over the Dee at Pont Cysyllte. It is 125 feet high, the supporting pillars being 52 feet apart. The aqueduct itself consists of a cast-iron trough, 320 feet long, 20 feet wide, and 6 feet deep. The earthen embankment which meets the aqueduct attains a perpendicular height of 75 feet at the point of meeting, and the whole aqueduct, including the trough, is 1,007 feet long. The piers supporting the trough have their foundation in hard sandstone, and are 20 feet by 12 feet at bottom, tapering to 13 feet by $7\frac{1}{2}$ feet at top. They are built solid for 70 feet from the foundation, and hollow, with 2 feet thickness of wall and one cross inner wall, for the remaining 50 feet. The water-way has a width of 11 feet 10 inches, the towing-path, which is 4 feet 8 inches wide, standing upon iron pillars over the water, by which simple and excellent arrangement there is no encroachment upon the water-way. The cast-iron plates forming the sides of the trough are strongly riveted to the bottom plates, and, wherever possible, ties and braces are introduced. The overhanging towing-path is itself a source of great strength to the side. In Fig. 13 we show a section of the cast-iron trough and towing-path. The entire trough is embraced within the four letters A B C D, the towing-path extending from A to E, supported by the pillar E E′; the cross-bar X acting as a brace or tie. The upright A A′ shows the protecting rail of the towing-path. The entire cost of the aqueduct and embankment was £47,018 6s. 7d., of which sum the iron-work cost rather over £17,000.

An important canal, the Gloucester and Berkeley, enables vessels of 400 tons burthen to pass up the Severn as far as Gloucester. It commences at Sharpness Point in that river, its entrance being protected from the south-west winds at that locality by a breakwater. The minimum depth of water throughout this canal is 18 feet.

The Grand Junction Canal, with its many ramifications, forms by far the most important system of internal navigation in this island. The total length of the system united by it is between 300 and 400 miles. The Blisworth tunnel, near Northampton, is an important piece of engineering connected with this canal. It is 3,080 yards long, $16\frac{1}{2}$ feet wide, and has a depth of 7 feet from the water-line to the bottom of the inverted arch, and a height from the same level to the top of 11 feet. The side walls are segments of a circle of 20 feet radius, and the top arch one of 8 feet radius. The sides and top are two bricks thick, and the bottom $1\frac{1}{2}$ bricks. The mortar was composed of 1 bushel of blue-lias lime to 3 of sand. At 6 inches below the water-line on each side of the tunnel are rails of fir, 5 inches square, to keep the barges off the walls. These are fixed by pieces of oak let into the brick-work, standing 9 inches off the wall. At every three yards a block of wood is fixed to the upper side of the rail, to act as a point for the bargemen to place their poles against. The soil through which the tunnel is cut is a hard blue clay, and cost £15 13s. per running yard. The cuttings forming the approaches to the tunnel cost $10\frac{1}{2}$d. per yard cube at one end, and 11d. per yard cube at the other end. The headings for the tunnel cost 36s. per yard run at one end, and 42s. 6d. at the other end. The tunnel pits or shafts were nineteen in number, some being 60 feet deep, and cost, including steining, 30s. per yard run in depth. The entire cost of the Grand Junction Canal was two millions sterling. It is 90 miles long from Braunston to Brentford, where it enters the Thames, the width at bottom being 28 feet, at the surface of the water 42 feet, and the depth 4 feet 6 inches. The chambers of the locks are 80 feet long, and 14 feet 6 inches broad. There are eight supply-reservoirs for feeding the locks, each reservoir containing about 9,000 cubic feet of water, and capable in the aggregate of re-filling a single lock 17,000 times. It is worthy of notice that the reservoirs not being all upon the same level, and there not being an independent supply to each, the water is pumped by steam-power from the lower to the higher ones.

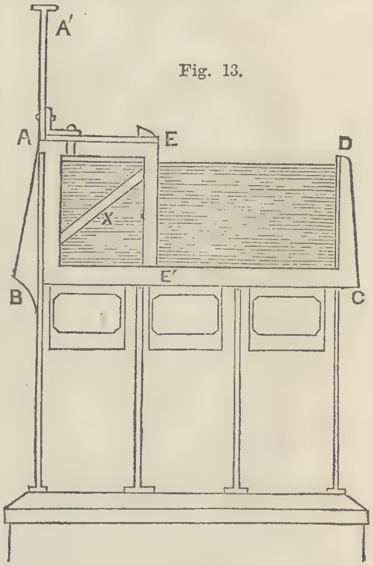


Fig. 13.

The Shropshire Canal, from Coalport to Donnington Wood, is the first canal on which the system of inclined planes was introduced. The originator was William Reynolds, of the Ketley iron works. The country over which this canal passes possesses a great scarcity of water, not sufficient to work locks. Hence the inclined planes were introduced. On the banks of the Severn is one of these planes 350 yards long, having a perpendicular height of 207 feet. A strong double line of rails is laid upon this plane to receive the boats with their carriages. The boats take a load of 5 tons, and when they arrive at the summit of the incline, pass by a level canal, $1\frac{3}{4}$ miles long, to the bottom of a second incline, 600 yards long and 126 feet high, where they enter a second level canal, which forms the summit of the system; after which the boats descend by other inclines to the other extremity.

The Thames and Medway Canal has a tunnel—now filled up and used as a railway—of $2\frac{1}{4}$ miles in length. This tunnel is driven through chalk of a very variable character, being in some places so soft as to crumble away before the miner, and in others so dense as to need blasting. The soil had in many spots to be supported by timber struts before the brickwork was built in: this varies from 14 to 18 inches. As the vaulting advanced, the space above the brick-work was filled in with chalk and lime mortar. The cutting of this canal, and the shafts connected with it, caused the water in the surrounding wells to sink so low that they had to be deepened to obtain a fresh supply; and when the salt water was admitted from the tide-ways, it pervaded the chalk and injured the quality of the water in these wells, the company being put to great expense in consequence of the damage. The width of water-way in the tunnel is 21 feet 6 inches at top, and 20 feet at bottom. The depth of water is 8 feet, the towing-path being 3 feet above the water. The greatest width of the tunnel is 30 feet.

The Harecastle tunnel, upon the Tetney Haven Navigation, was constructed by Brindley. It is 2,888 yards long, and being 9 feet wide, and only 12 feet high, it was necessary to propel the boats by employing a class of men called "leggers," who, lying upon their backs upon the freight, pushed against the sides and top with their feet. It occupied two hours to push a boat through in this manner. A second tunnel was constructed in 1824, by Telford, at a distance of 26 yards from Brindley's, and is a few yards longer than his. The width is 14 feet, and height 16 feet; 4 feet 9 inches of the width is occupied by the towing-path, but as it is supported over the water in the same manner as that in the aqueduct at Pont Cysyllte, the water-way is not interfered with. The mortar with which the bricks are set is impervious to water. Nearly 9,000,000 bricks were used in the construction of the tunnel, shafts, and culverts, and the total cost of the work, which scarcely occupied three years in completion, was £112,681.

Looking abroad, we find various schemes have been proposed, and in some instances carried out, for cutting canals through short necks of land, whereby thousands of miles of ocean navigation might be avoided. Amongst those only proposed is the Darien ship canal, intended to obviate the transhipment of freights passing between the Atlantic and Pacific Oceans, without the alternative of passing round Cape Horn. The first idea of such a scheme dates from 1771. Many surveys of the isthmus have been made from time to time, and particular attention paid to the northern portion, in consequence of the Lake of Nicaragua offering an apparently favourable feature in a line of navigation at this part. This extensive lake has an average depth of fifteen fathoms, and is separated from the Pacific sea-board by only 15 miles of land. This land, however, consists of a mountain ridge 615 feet above the Pacific, and 487 feet above the lake; and to cut through the ridge for a canal 30 feet deep and 50 feet wide—the dimensions necessary for a ship-canal—would necessitate the excavation and removal of nearly 5,000,000,000 cubic feet. Moreover, the ridge is volcanic, and it would be impossible to obtain a supply of water to feed a canal if, as an alternative to such a cutting as that alluded to, a portion of the ridge were overcome by locks, and the canal cut only through the upper portion. The lake is connected with the Atlantic by the river San Juan, whose length from the lake to its mouth is 119 miles. There are no cataracts or falls in the river, but a few rapids; it is at all times navigable for boats drawing from 3 to 4 feet of water, whilst the fall averages 1 foot per mile. It might therefore appear practicable to improve the navigation of the San Juan so as to make it available for a canal, but the apparently insuperable obstacles presented by the ridge upon the west coast makes this advantage of no avail. Another survey of this route was made in 1850-1, in which it was proposed to cut a canal $28\frac{1}{4}$ miles long, with 6 locks, on the Atlantic side of the lake, and to canalise the San Juan by means of 7 dams and 8 locks. The communication between the lake and Brito, on the Pacific, was to be effected by a canal $18\frac{1}{3}$ miles long, with 14 locks. The summit of the ridge to be cut through on the Pacific side was found to be 46 feet above the lake, and the width of the ridge to be 8 miles. An artificial harbour would have been required at Brito. The whole length of the navigation would have been 194 miles, of which $56\frac{1}{2}$ miles would have been by Lake Nicaragua, and the estimate for a canal 20 feet deep would have been £10,000,000 sterling. Had this canal been constructed, it was estimated that a vessel could have passed from the Atlantic to the Pacific in 77 hours. The objections to this route are so great and so numerous that the idea has been finally abandoned. Amongst the objections are the fearful insalubrity of the climate, owing to the swampy character of the banks of the San Juan. Upon this point it may be stated that Lord Nelson mentions that in 1779, when captain of the *Hinchinbrook*, he was engaged in an expedition to take the fort of San Juan, and the cities of Granada and Leon, and in one night, out of a complement of 200 men, 87 took to their beds, and not more than 10 of that crew survived, Nelson himself being carried ashore at Jamaica in almost a helpless state. The frequency of earthquakes, and the breaking out of fresh volcanoes, would also render any works undertaken very insecure in this district. Besides these serious objections, the mouth of the San Juan could never be made a suitable entrance for a ship-canal, as the sand-spit at its seaward face is always shifting; and, indeed, recent information is to the effect that the harbour is almost completely filled up, and the river has forced a channel for itself elsewhere.

Turning from a mere problem, we shall conclude the subject with a short reference to that most important, and now completed undertaking, the Suez Canal. This vast engineering work is made large and deep enough for a ship-canal, and enabling vessels to avoid the passage round the Cape of Good Hope, saves 3,000 miles on the voyage to India. It is 72 miles long, extending from Port Said, on the Mediterranean, to Suez, at the northern extremity of the Red Sea. Two distinct engineering works are comprised in the works undertaken by M. Lesseps—namely, the construction and maintenance of a broad and deep water channel on one level between the above named points, and also the maintenance of a supply of fresh water for the wants of the population congregated along the line of the canal, and especially at the two extremities. This latter undertaking was necessary in consequence of the avoidance of the Nile in any of its branches, and from the saline and arid character of the country through which the canal passes.

The construction of enormous jetties became necessary at Port Said, in order to protect the harbour, or canal entrance, from the action of the prevailing wind—the north-west. These jetties are formed of immense blocks of artificial stone, each weighing 20 tons, and were constructed on the spot. From this point the canal runs in a perfectly straight line for 40 miles to Lake Timseh, through which it passes, and which, previous to Lessep's operations, had been dried up for a lengthened period. The channel has throughout a minimum depth of 8 metres, and is in many parts 26 feet deep; being 190 feet wide at top, and 100 feet wide at bottom. The amount of soil excavated exceeds 147,000,000 cubic yards, and was performed by the continued action of powerful steam-dredging machines. The cost of excavation has exceeded £4,000,000. The entire undertaking displays an amount of indomitable perseverance and engineering talent rarely united in a single individual.

TECHNICAL DRAWING.—XXXIII.

DRAWING FOR MACHINISTS.

THE STEAM-ENGINE (*continued*)—GENERAL VIEW OF ENGINE.

FIGS. 338 and 339.—The side and end elevation show all the before-named details, and also the bed and fly-wheel in their proper places as fitted together and ready to work. It will be

easy to follow each detail into its place. There are only two elevations of the engine-bed; its thickness would be $\frac{5}{8}$ inch at the sides and $\frac{3}{4}$ inch at the top, which is planed all over and made smooth. This engine is not an example of the cheapest form of construction, but is very strong and durable, and suited for high pressures. It is also a good specimen of suitable beauty and fitness of form for such work.

This set of drawings illustrates the proper system for sending plans from the drawing-office into the workshop: the details are given in such a manner that a good workman would find no difficulty in understanding them, and making the engine without further instructions. It is very desirable to put dimensions for all the principal parts where drawings are not made full size; but for such an engine as this one, many of the details might be made full size, and the rest to a large scale or half size. Figures upon a drawing save workmen much time and conduce to accuracy; very few are given in these details, for the sake of avoiding confusion in the lines.

In making drawings the lines for dimensions should be drawn with red or blue ink.

FOUR-INCH SAFETY-VALVE (*scale, three inches to one foot*).

When steam is raised in a closed boiler its pressure gradually accumulates, and would at last burst the boiler unless means were provided for its escape. Safety-valves are arranged for this purpose, and their general principle is that of placing a known weight upon a valve, so that the steam shall lift it and escape whenever its pressure becomes greater than is desired.

Fig. 340 is the plan, and Fig. 341 the side view, partly in section to show details of construction. At the extreme left side of the sheet is a fulcrum or fixed centre for the safety-valve lever, and at the opposite side a heavy weight. Close to the fulcrum is a pointed link, which presses upon a brass valve. As the distance between the fulcrum and valve-centre is $3\frac{1}{2}$ inches, and between the fulcrum and weight (when at the end of lever) is 28 inches, every pound will press with eight times the force—viz., 8 pounds—on the valve by the well-known principle of a lever. Knowing the area against which steam presses, it is not difficult to calculate the resistance offered by the weight and lever, so that any desired pressure of steam may be enabled to lift the valve and escape. These valves and seats are made of gun-metal, an alloy of copper and tin, and the bearing surfaces are ground together so as to be steam-tight. A small groove is turned in the conical seat, and a piece of string inserted before it is driven into position, so as to prevent any leakage. The cup form of the cast-iron pipe is adopted so as to cause any escape of steam to rise upwards, instead of spreading out like a flat disc.

Figs. 342 and 343 represent the wrought-iron tongue which is cast into the valve-weight, and forms a means of suspending it from the lever. The roughened corners are intended to give a greater hold to the cast iron when it is poured over the tongue in a melted state.

A spring may be used instead of the weight, and in many positions, such as on locomotive engines, it has been found more convenient.

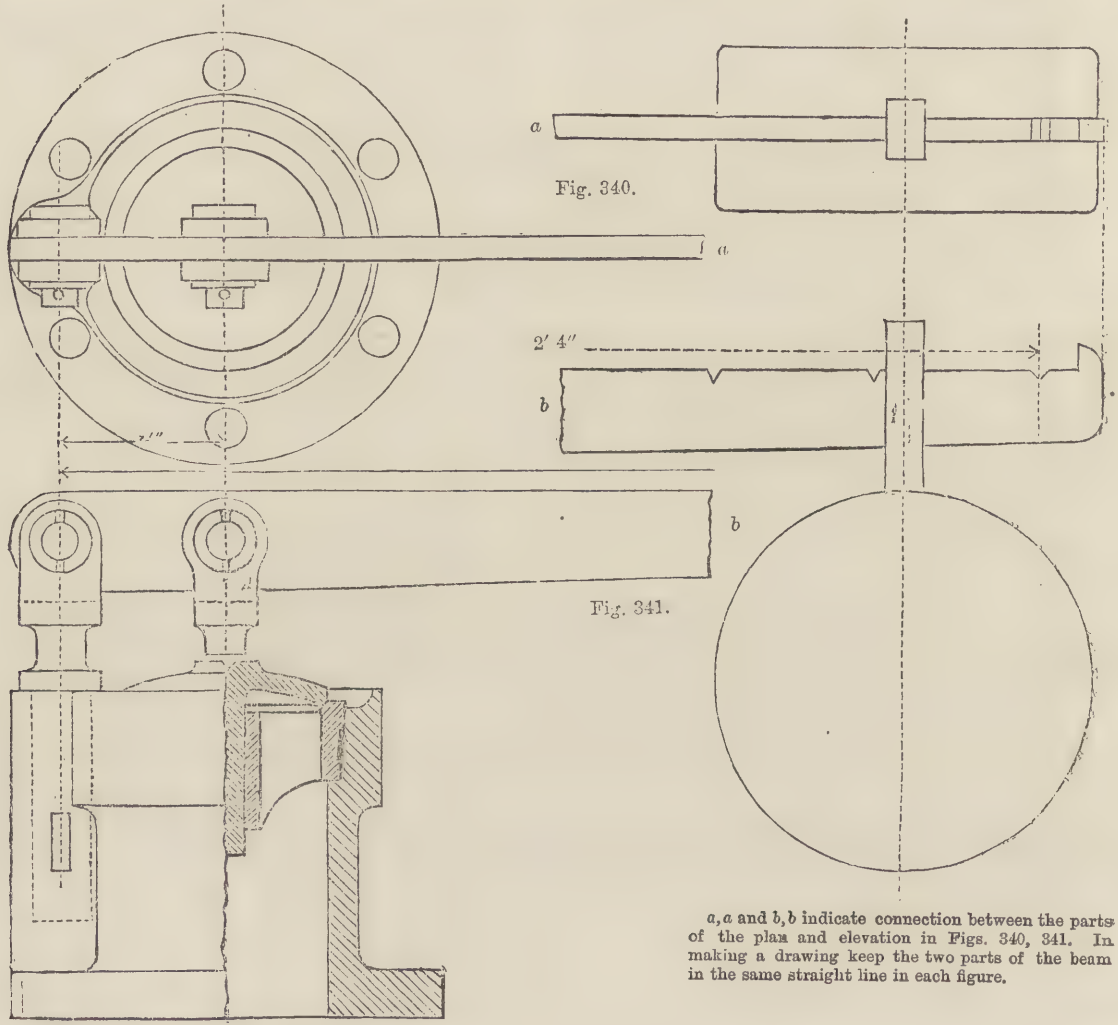


Fig. 340.

Fig. 341.

a, a and *b, b* indicate connection between the parts of the plan and elevation in Figs. 340, 341. In making a drawing keep the two parts of the beam in the same straight line in each figure.

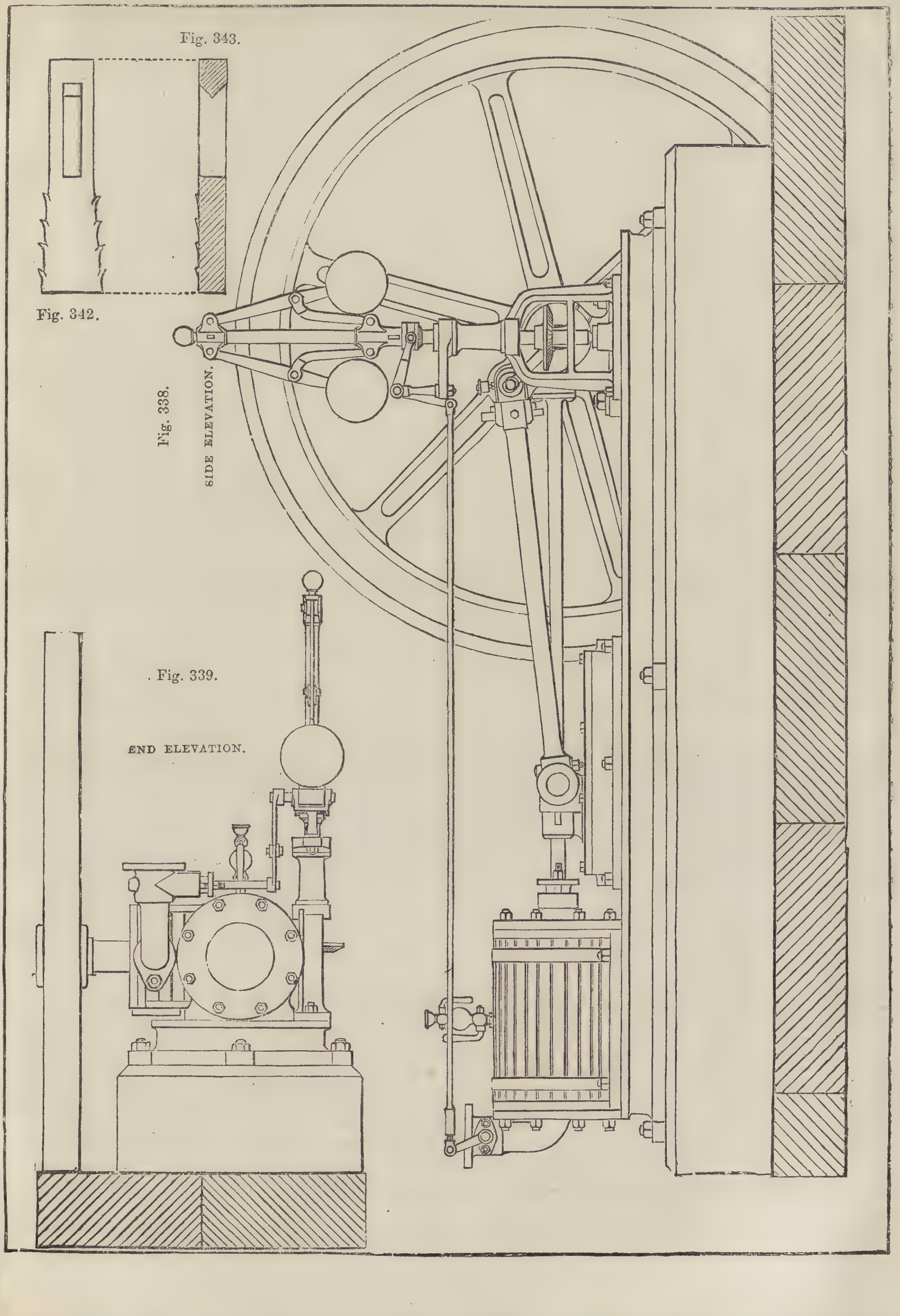


Fig. 343.

Fig. 342.

Fig. 338.

SIDE ELEVATION.

Fig. 339.

END ELEVATION.

NOTABLE INVENTIONS AND INVENTORS.

XII.—THE COTTON MANUFACTURE (*concluded*).

BY JOHN TIMBS.

We must now return to Hargreaves' frame, in which a number of previously prepared rovings were drawn out to a greater fineness and twisted into yarn. Now Arkwright's invention prepared the rovings and spun the yarn; Hargreaves' could do the latter only. The former was best adapted for producing firm warp yarn; the latter for spinning the finer kinds used as weft. The union of the principles of both was necessary to perfect the art of spinning. The rollers of Arkwright and the motion from the spindles of Hargreaves are united in the mule of Crompton, which he invented in 1797, and, after many unsuccessful attempts, made self-acting; so that one spinner can make 800, 1,000, or even 2,000 threads at once. "The rovings," says Mr. Syme, "part the rough rollers, which turn for some time, and then stop. The spindles are placed on a carriage, which moves from the rollers after they have ceased to turn and draw out the thread; the spindles revolve, the requisite twist is communicated to the fibres, and the thread thus spun is then wound on the bobbins as the carriage advances towards the rollers." As soon as the whole of these processes are performed, the mule disengages itself from those portions of the machine which have been used to propel it, and the attendant returns it again to the carriage, to perform its work afresh. To give an idea of the value of this invention: while the water-frame is capable of spinning a pound of cotton to the length of nineteen miles, or forty hanks, the mule has not met with any limit short of 950 miles to the pound of cotton, or 2,000 hanks.

Samuel Crompton was born in 1753, at Firwood, near Bolton, his parents occupying a farm, and, as was the custom of that time, employing their leisure hours in carding, spinning, and weaving. They removed, when Samuel was five years old, to a portion of the neighbouring old mansion called "The Hall in the Wood." The boy was well educated in Bolton, but "his little legs became accustomed to the loom almost as soon as they were long enough to touch the treadles." When only sixteen years of age he spun on one of Hargreaves' jennies, with eight spindles, the yarn of which he afterwards wove into quilting, and thus he was occupied for the five following years.

At his solitary loom, in the Old Hall, he became prematurely a thinker, and cultivated a taste for music, which led to the first trial of his mechanical skill in making a violin. He was master of Hargreaves' invention, the jenny, and he was personally known to Arkwright, whose reputation as an inventor now rang through Lancashire. In the dining-hall of the old mansion, Crompton, in 1774, commenced the construction of his spinning machine, which for many years was known as "the Hall in the Wood Wheel." It took him five entire years to mature his improvement, working entirely alone, and he tells us that he succeeded at the expense of every shilling he had in the world; all this labour being in addition to his every-day work. He toiled late and early: he devoted every shilling he could spare to the purchase of the requisite tools; and, aided by his clasp-knife, he at length triumphed. His machine was first called "the Muslin Wheel," because it was available for yarn for making muslins, and it got the name of the "Mule," from its partaking of the two leading features of Arkwright's machine and Hargreaves' spinning jenny; but it is certain that when Crompton constructed his machine he knew nothing of Arkwright's discovery.

As soon as Crompton had completed his first mule, in the year 1779, to save it from destruction by the Blackburn spinners and weavers, he took it to pieces, and concealed it in a loft at the Old Hall. Here it remained for many weeks, but in the same year the wheel was re-constructed, and out of its first earnings Crompton bought himself a silver watch. In 1780 he married. Assisted by his wife, he industriously spun at the Hall, his yarn producing higher counts and an improved quality, for which he readily obtained his own prices, but he could not satisfy one-hundredth part of the demand. The Old Hall was now besieged not only by purchasers, but others to get at the mystery of the wonderful new wheel. Admission was denied, when many, who climbed up to the windows, were blocked out by a screen; but one inquisitive seeker concealed himself for some days in a loft, and watched Crompton at work by means of a gimlet-hole pierced through the ceiling; and thither Arkwright travelled sixty miles to endeavour to discover the secret of the new wheel, which all but eclipsed his water-frame. But Crompton found it impossible to retain the secret of his machine; he had no patent, or the means of purchasing one; and, rather than destroy the whole, he gave it to the public, when some "manufacturing friends" promised to raise for him £60; yet the list of half-guinea subscribers of this paltry amount contains, says Mr. Gilbert French, "the names of many Bolton firms of great wealth and eminence as mule-spinners, whose colossal fortunes may have said to have been based upon this singularly small investment." In the five following years the mule was generally employed for fine spinning throughout the manufacturing districts.

Before 1785, Crompton removed to a farm-house near Bolton; and there, besides farming, he worked secretly at his machine in the upper storey of his house. Curious visitors still came, and among them was Mr. (afterwards the first Sir Robert) Peel, who attempted to get at the mule in Crompton's absence, but was defeated. He subsequently offered the inventor a lucrative situation, and even a partnership in his establishment, both which Crompton declined to accept. Crompton next, with £500 subscribed for him at Manchester, rented a factory storey at Bolton, and there had two mules, with the *power* to turn the machinery. He then submitted his machine to the Royal Society and the Society of Arts, but by neither was it entertained. The public had got it, and that was enough. Crompton then visited the manufacturing districts, where he found the number of his mule spindles in use to be 4,600,000, spinning 40,000,000 pounds of cotton wool in a year; that 70,000 persons were engaged in spinning, and 150,000 more in weaving the yarn so spun; and that a population of full half a million derived their daily bread from the machinery his skill had devised. Our inventor then petitioned Parliament for remuneration, and Mr. Perceval, the Chancellor of the Exchequer,* was ready to propose a handsome grant of money, when it was frustrated in a shocking manner. On May 11, 1812, Crompton was standing in the lobby of the House of Commons, conversing with Sir Robert Peel and Mr. Blackburne, when they were joined by the Chancellor of the Exchequer, who remarked, "You will be glad to know that I mean to propose £20,000 for Crompton; do you think it will be satisfactory?" Crompton retired, and did not hear the reply. He was scarcely out of sight, when the madman Bellingham came up, and shot Mr. Perceval dead. By this frightful catastrophe Crompton lost £15,000. Six weeks intervened before his case could be brought before Parliament, and then Lord Stanley moved that he be awarded £5,000, which the House voted without opposition. No reason was given for the reduction of Mr. Perceval's proposition: the smaller grant was inadequate, whether measured by the intrinsic value of Crompton's services, or by the rate of Parliamentary rewards to other inventors. When he returned to Bolton with £5,000, instead of a great fortune, he heard the bitterest reproaches from his family. With the above sum Crompton entered into manufacturing speculations with his sons, but unsuccessfully; and as he advanced in years, some of his friends subscribed, and purchased him an annuity of £63. A second application in his behalf was made to Parliament, but failed. This must have been very mortifying to Crompton, who was one of the most sensitive as well as honourable of men, and who is known to have declared to one of his most stedfast supporters in Parliament, "I only request that the case may have a fair and candid hearing, and be dealt with according to its merits."

Worn out with cares and disappointments, Crompton died at Bolton on the 26th of June, 1827, at the age of seventy-four, and was followed to the grave by a host of Bolton worthies. A statue of Crompton, in bronze, by Calder Marshall, was erected in the market-place at Bolton, in 1862; though to be treated with respect after death is but a poor recompense for being neglected while we are living. "Justice exacts," says Samuel Johnson, "that those by whom we are most benefited should be most honoured."

* Mr. Perceval is spoken of here as "Chancellor of the Exchequer," and rightly enough. It must, however, be remembered that he was Premier as well, and the head of the Administration from October 30, 1809, to May 11, 1812. Both offices were also held conjointly by Pitt, Canning, and Peel, and recently by Mr. Gladstone.

Mr. French, in his "Life and Times of Samuel Crompton," with graceful earnestness, has vindicated his claim and character, and thus rescued him from neglect. It may safely be asserted that Crompton's mule is the fulcrum which sustains that mighty lever, the cotton trade, the most valuable and most powerful of our national resources. As the jenny is now almost disused, and all the finer yarns are spun exclusively upon the mule, its importance and value continue to increase. The principle of Crompton's invention has remained unchanged; while modifications, improvements, and auxiliaries have increased its productive power a hundredfold. Meanwhile, the results of Crompton's genius have been practically commemorated upon the site of his invention. Near the Hall in the Wood rises an octagonal chimney-shaft 366 feet in height, in connection with the steam-engines and furnaces in a huge factory, where some thousands of men and boys are employed in making mule-spinning machinery, and in the production of thousands of mule-spindles. The old Hall has become the veritable centre of the existing cotton manufacturing district. "Could we," says Mr. French, "tie a cord, twenty miles in length, to the top of the tall chimney that marks the spot, and sweep it round the country, the circle then formed would embrace the populous towns and teeming villages engaged in spinning and weaving cotton. They radiate from that centre with compass-like regularity; Manchester, Preston, Oldham, and Blackburn being the cardinal points."

The triumphs of the combination here described were not confined to spinning. It had been repeatedly but unsuccessfully attempted to weave cloth by machinery before. It was effected by a singular accident. Edmund Cartwright, a brother of Major Cartwright, the politician, had been educated for the Church in the University of Oxford, had written and published several poems, and had reached his fortieth year before he had given any attention to mathematics. Mr. Cartwright, in 1784, being at Matlock, in the company of some gentlemen of Manchester, maintained the practicability of inventing a machine to weave the vast additional quantity of cotton spun by Arkwright's machinery. It occurred to Cartwright that, as in plain weaving, according to the conception he then had of the business, there could be only three movements to follow each other in succession, and little difficulty in producing and repeating them. He then had constructed upon this principle a machine, and getting a weaver to put in the warp, to his great delight, a piece of cloth was the result. The warp was laid perpendicularly: the reed fell with the force of at least half a hundredweight, and the springs which threw the shuttle were strong enough to have thrown a Congreve rocket. His machine was rude and awkward, for his own loom was the first he had ever seen. It was opposed both by prejudiced manufacturers and their workmen, and a mill containing 500 of his looms was wilfully burnt down. He, nevertheless, persevered, but after taking out several patents, and spending upwards of £40,000, he relinquished all hope of accomplishing his object. In 1809, however, Parliament voted him £10,000 for "the good service he had rendered the public in his invention of weaving." He died in 1823, in the eighty-first year of his age.

Power-looms remained unprofitable until it was discovered, in 1803, that the warp might be dressed before being put into the loom, by a machine consisting of eight rollers, four at each end of a frame. These rollers are brought from the warping frame, and the yarn passes between two rollers, the lower one of which dips into a reservoir of thin paste, and thus transfers a coating of starch to the cotton. The yarns afterwards pass over and under brushes for rubbing into the fibres, then over a heated copper box to dry them, and they are ultimately coiled round the warp beam of the loom. The construction of the machine and method of dressing have since been improved, and cloth is now woven, by the help of steam, with wonderful rapidity and extent. A steam-engine of 40 or 60 horse-power gives motion to thousands of rollers, spindles, and bobbins for spinning yarn, and works four or five hundred looms besides. This gigantic spinner and weaver needs very little assistance from man. It undertakes and faithfully discharges all the heavy work of putting shafts, wheels, and pulleys in motion; of throwing the shuttle, working the treadles, driving home the weft, and turning round the warp and cloth-beams. One man may now do as much work as two or three hundred men ninety years ago. Power-looms are among the most extraordinary machines in a factory. The operations of one of these looms being minuted with a watch, have been seen to weave seventy-two square inches of cloth in a minute, without any human being attending to it.

The substitution of machinery in place of hand-labour in spinning and weaving has been productive of the most beneficial consequences, since the inventions of Arkwright and Watt were made. At first, the various operations of beating, carding, roving, and spinning were household operations; but progressively, with a view to economy of time and quickness, they led to the building of factories; and the concentration of them under one roof, with a propelling power of water or steam, gave a united and combined action to all the processes, which caused them to be carried on with the precision of clockwork. Nor has improvement been obtained in one branch of industry, but in all. Really good small steam-engines and mill-gearing could not be manufactured when mechanical power was first introduced. Now, in place of heavy shafts of wood, and cast-iron huge wheels and pulleys, we have light wrought-iron rods, smaller wheels, quintupled velocities, and diminished friction.

In a cotton-mill the most striking actions of machinery are those which involve not only swift, irresistible motion, but also transformation of the materials on which the moving force is exerted. "In the basement storey revolves an immense steam-engine, unresting and unhasting as a star, in its stately, orderly movements. It stretches its strong iron arms in every direction throughout the building; and into whatever chamber you enter, as you climb stair after stair, you find its million hands in motion, and its fingers, which are as skilful as they are nimble, busy at work. They pick cotton, and cleanse it, card it, rove it, spin it, dye it, and weave it. They will work any pattern you select, and in as many colours as you choose, and do all with celerity, dexterity, and unexhausted energy and skill; and with the speed of racehorses transform a raw material, originally as cheap as thistle-down, into endless useful and beautiful fabrics." (Professor George Wilson.)

Mr. Tuffnell states that, in the fine spinning-mills, he has seen a pound of cotton stretched to the incredible length of 294,000 yards, or 167 miles, and then sold for twenty-five guineas, the original cost of it having been 3s. 8d.

But what a concentration of mental work is requisite to produce these wonderful machines! In a factory, into which the cotton is taken in a raw state, and is brought out as cloth, there is not one of the numerous machines through which it has to pass, including the steam-engine, which moves them all, that does not seem to demand the utmost stretch of human ingenuity to bring it to its present state—not one that does not condense in its formation the result of at least a hundred patents, or that has not required in its invention the united efforts of at least a hundred minds.

We conclude with a few interesting statistics. Cotton-growing in the United States began with the century, and rose from 400,000 bales in 1820 to 5,000,000 bales in 1859 and 1861, the two most productive years. The price in the same period fell from 50 cents to 10 cents a pound. Since the close of the civil war, cotton culture rapidly revived, and the crop of the season following it reached nearly 4,000,000 bales, a quantity only surpassed in 1859 and 1861. The war between France and Germany, however, operated disastrously on prices, and cotton that was selling at 25 cents a pound in the previous year was quoted at less than 15 cents. The culture, however, again fast revived. In 1840 Mr. Buxton stated there were employed in our cotton manufacture about £2,000,000 of fixed and £20,000,000 of floating capital invested. The total yearly produce of the manufacture amounted to £40,000,000. 1,500,000 persons then earned their bread by it.

The Board of Trade accounts state that the import of raw cotton into the United Kingdom in the first quarter of the year 1871 reached the large amount of 5,318,511 cwt., stated to be of the value of £18,738,015. The quantity is more than double that of the corresponding period of either of the two preceding years, but the price shows a very great decline. Above half a million cwt. came to us from India, and above half a million from Egypt; the quantity sent in from the United States was not less than 3,949,190 cwt. The exports from this country of imported cotton in the three months already named exceeded a million cwt.

APPLIED MECHANICS.—XIII.

BY ROBERT STAWELL BALL, M.A., LL.D.,
Astronomer-Royal for Ireland.

THE DRILLING MACHINE.

THE drilling machine is of the utmost use in the workshop. Holes are constantly required to be produced, either for the purpose of receiving bolts, or for numerous other purposes. Many different forms of drill are in common use. We have selected for description in the present lesson one of the most ingenious which has been invented. This drill is shown in the illustration below (Fig. 1).

For drilling, the tool must receive two distinct motions—one that of rotation, the other that of advance parallel to its axis; the work being held steadily. In this the drill may be contrasted with the turning lathe and the planing machine. In both of these the work is moved, while the tool is also moved. Having to give the two motions to the tool of the drilling-machine, instead of being able to give one of them to the work, makes the drilling machine a little more complicated than either of the machines already described, as we have to provide for the two motions simultaneously.

S represents the point of the drill; the work, which is not shown, is supported upon a table underneath the drill, which can be moved in two directions, so as to bring the work beneath the drill in the proper position. The drill is fastened to a screw, T; this screw works in the nut E. The toothed wheel X is fastened upon the nut E, while the wheel Y is fastened upon the screw. A, B, and C are three pulleys. A is an idle pulley; B is keyed upon the shaft that carries N; and M and C are attached together. It will be noticed that M and N are not of the same size, nor are X and Y. We shall let m, n, x, y represent the numbers of teeth in the four wheels, M, N, X, Y. When the band is upon A the machine is at rest; when the band is upon B, N and Y are turned round, and the drill is brought down to its work by being screwed out of its nut. When the band is upon C, the nut E is made to revolve, and the screw is drawn up into its nut, and raised from the work. But when the band is upon both B and C the drill revolves and the nut revolves; but the drill screws out of the nut faster than the revolution of the nut brings it back, and thus a slow motion of advance is combined with the rotation of the drill.

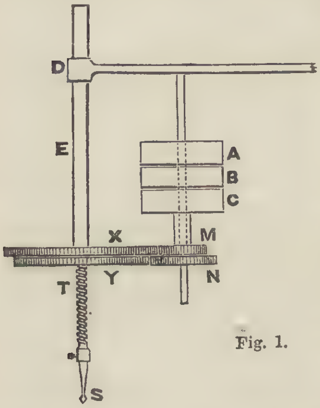


Fig. 1.

Let k represent the number of threads in the inch upon the screw T.

For one revolution of the pulley B, the screw will have made

$$\frac{n}{y} \text{ revolutions,}$$

and will therefore have been depressed by

$$\frac{n}{y} \times \frac{1}{k} \text{ inches;}$$

but on account of the revolution of the pulley C, the nut E has made

$$\frac{m}{x} \text{ revolutions,}$$

and has therefore raised the screw by

$$\frac{m}{x} \times \frac{1}{k} \text{ inches.}$$

Hence the real advance of the screw being the difference between the amount by which it is raised and lowered is

$$\left(\frac{n}{y} - \frac{m}{x}\right)\frac{1}{k}.$$

This is the amount by which the drill is lowered when it has made $\frac{n}{y}$ revolutions.

Therefore, the amount by which the drill descends for one revolution is

$$\left(\frac{n}{y} - \frac{m}{x}\right)\frac{1}{k} \times \frac{y}{n} = \left(1 - \frac{my}{xn}\right)\frac{1}{k}.$$

This quantity can have any value by proper selection of the wheels, the only condition to be attended to in the choice of wheels is that

$$x + m = n + y,$$

because if this equation were not satisfied, the two pair of wheels could not be adjusted to gear simultaneously.

To illustrate these formulæ by an example, we shall suppose that the screw has three threads to the inch; that is, $k=3$; and that $m = 40$, $x = 120$, $n = 50$, $y = 110$. These numbers satisfy the relation—

$$x + m = n + y.$$

The expression $\left(1 - \frac{my}{xn}\right)\frac{1}{k}$ becomes

$$\left(1 - \frac{40 \,.\, 110}{120 \,.\, 50}\right)\frac{1}{3} = \frac{1}{11 \cdot 2}.$$

Therefore, for each revolution of the drill its point will advance about the eleventh part of an inch. In fact, the drill is much the same as if it were simply attached to a screw containing eleven threads to the inch, and rotating on its nut.

This arrangement can be made to produce a very slow advance of the drill. Thus, suppose $m = 40$, $x = 120$, $n = 41$, $y = 119$, the advance is

$$\left(1 - \frac{40 \cdot 119}{41 \cdot 120}\right)\frac{1}{3} = \frac{1}{92}.$$

Thus the drill must perform 92 revolutions before it will have advanced one inch.

MACHINERY USED IN THE MANUFACTURE OF SUGAR.

The preparation of sugar before the product is brought into the form in which we are familiar with it, involves two distinct branches of manufacture. One of these, the preparation of raw sugar, is conducted at the place where the sugar is grown; the other, called sugar refining, is usually performed at home.

It is not within our province to give in the present paper a description of the technical details of the manufacture, except so far as may be necessary to enable the action of the machines used to be understood; many of the processes come more properly within the province of the chemist than of the mechanic.

There are two important stages in the manufacture in which machinery is used. The first is in the expression of the raw juice from the cane, and the second is the separation of the crystals of refined sugar from the liquor in which they are contained. There are, of course, multitudes of minor mechanical contrivances for hoisting, pumping, etc., used in various parts of the manufacture; but as these are not peculiar to this branch of the mechanical arts, we shall not further allude to them in this lesson.

We shall describe the machinery used in these two different processes.

The juice from which the sugar is extracted is expressed by pressure from the sugar-cane. The cane is a long stalk about two inches in diameter; the outside is hard, the inside is soft, and contains the juice which it is the object of the cane-mill to extract.

Fig. 2 represents in a diagrammatic manner the principle of the cane-mill which is most usually employed. A, B, C are three rollers with flanges at their extremities to prevent the canes from escaping; they are made of cast iron. In some of the larger works these rollers are very massive, reaching the length of six feet, and a diameter of thirty inches; the roller C is sometimes fluted longitudinally, so as to draw in the cane with certainty; but this is, however, not necessary, and as the cane is much crushed and injured by the fluting, the roller is frequently smooth. The three rollers are made to revolve together, by means of toothed wheels, not shown in the figure, and the whole

is worked either by a steam-engine, or by the power of wind or water.

D is a flat table, upon which the canes are strewed to be delivered to the first pair of rollers, A, C. These rollers are about a quarter of an inch distant from each other. The space can be regulated by means of screws. The cane is thoroughly crushed

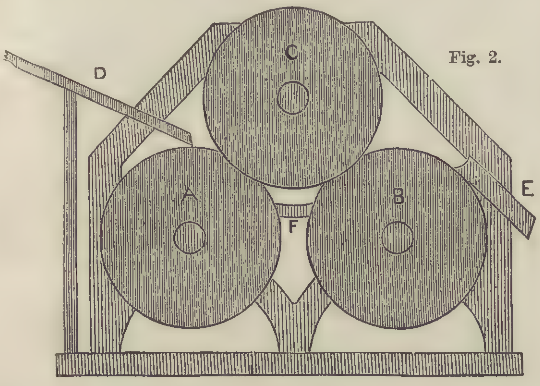


Fig. 2.

between the first pair of rollers, A and C, and rendered into a fit condition to receive the extreme pressure which the compressed mass receives between the rollers B and C.

At F is a plate upon which the crushed canes, after passing the first pair of rollers, are deflected so as to pass between the rollers B and C. These rollers are so close together that a sheet of ordinary writing-paper would only just pass between them. The canes submitted to this great pressure yield up the sweet juice contained in their cells; this juice trickles from the rollers into a trough placed to receive it, whence it is conveyed to vessels in which the process of preparing the raw sugar is commenced.

The rollers being so close together are more or less liable to jam, when an unusual quantity of cane is delivered to them. Such a sudden cessation of motion in so heavy a piece of machinery would be productive of injury, if not to the rollers themselves, at all events to the gearing by which their motion is sustained. Different methods are adopted to evade this difficulty. In some cases the rollers are turned by the aid of what are called friction wheels. The nature of friction wheels will understood from the annexed cut (Fig. 3).

Instead of the wheels being toothed on the circumference, there are a series of ridges which fit into corresponding grooves. When the wheels are pressed together, the friction causes the revolution of one of the wheels to make the other wheel revolve. If, however, the wheel which is being driven be stopped, or experience some very large resistance, no accident occurs, as the driving wheel merely slips upon the other without turning it round. All that is necessary is that the friction between the two wheels shall be a little greater than the force necessary for driving the cane-mill in its ordinary condition.

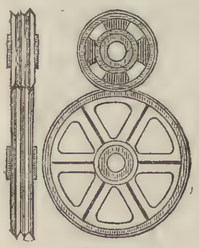


Fig. 3.

Another method of avoiding accident to the machinery by the jamming of the rollers depends upon a different principle. The rollers are usually adjusted at the proper distance by screws, but it is evident that, provided one of the rollers could be pressed towards the other with sufficient force, the screws may be dispensed with. This is the principle of the second method referred to. The roller B (Fig. 2) is urged towards the roller C by severe pressure produced by levers and weights: when an undue strain comes upon the rollers, the roller B is pushed away from C, and the obstruction is enabled to pass.

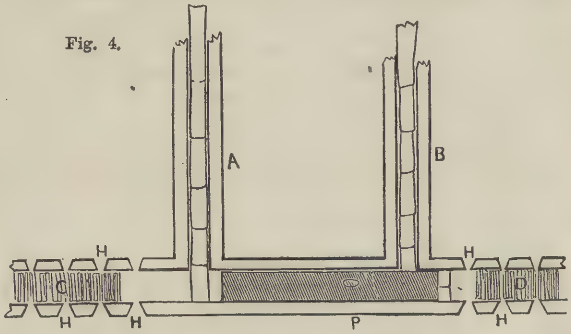
It is found by experience that a greater per-centage of juice is extracted from the cane when the rollers move slowly, at about the rate of two or three revolutions per minute, than when they have a higher velocity. The canes, after the juice has been expressed, are used as fuel for supplying the fires when heat is required in the subsequent treatment of the juice.

A considerable per-centage of the juice remains in the canes after having been submitted to the cane-mill. This juice, and of course the sugar contained in it, is lost. A cane-mill has been proposed by Mr. Bessemer, with the object of more completely extracting the juice from the cane than is possible in any mill in which the action is conducted by rolling. A diagram of the principle of this mill is shown in Fig. 4.

P is a solid plunger, which oscillates to and fro in a tube. The plunger is driven by a crank, and receives considerable power with the aid of the inertia of a fly-wheel. The canes are supplied to the mill by the vertical tubes A and B. The plunger, in the position shown in the figure, is about to move towards D; in its passage it cuts off the end of the cane in the tube B, and compresses the segment thus cut off against the mass of bruised cane D. The juice which flows from the cane escapes through the holes H, H in the tube. These holes are conical, with the narrow end outside to avoid clogging. On the return of the plunger to C a segment from the end of the cane in A is cut off, and has its juice expressed. A new length of cane in B descends into the tube to be ready for a fresh operation.

Thus two canes are supplied to each tube at the same time, and several plungers and tubes can be worked by the same engine. It is believed that by this process the juice is more completely expressed than by rolling. Not only is sugar saved, but the compressed canes are drier, and therefore in a fitter condition for fuel, and this is a very important consideration in many of the colonies, where fuel is scarce and expensive.

The treatment of the juice by evaporation, necessary for the

Fig. 4.


extraction of the raw sugar, does not involve any very special machinery. We shall therefore pass on to the mechanical appliances made use of in the process of refining the sugar.

The most interesting part of the process of sugar refining, from a mechanical point of view, is the application of centrifugal force to the separation of the crystals of sugar from the liquid in which they are contained. After the syrup has been concentrated in the vacuum pan crystals form throughout the mass, which becomes something of the consistence of mortar, and is of a brownish colour. When intended for making sugar-loaves this mass is placed in a mould of the proper form, and the liquid portion trickling away leaves the loaf in the form in which we are familiar with it; but when the crystalline soft sugar is to be made, centrifugal force comes into play. We shall calculate the magnitude of this force, referring the reader to the lessons in Mechanics for the demonstration of the theorems which will be used.

If a point be moving round in a circle, of which the radius is R, and T the time of revolution, the magnitude of the centrifugal force is

$$4\frac{\pi^2 R}{T^2}.$$

We shall suppose that R equals two feet, and that the particle makes ten revolutions per second; the magnitude of the force is therefore—

$$4 \times \left(\frac{22}{7}\right)^2 \times 2 \times 100.$$

This quantity reduces to 7884. The force of gravity is 32, therefore the ratio of the centrifugal force to gravity is 7884 ÷ 32. Hence the centrifugal force is about 246 times greater than the force of gravity.

We learn from this example how great is the force which can

be produced to expel the water from between the crystals of sugar. Each particle of water is urged towards the exterior with a force equal to 246 times the weight of the particle of water.

The apparatus consists of a large iron cylinder, the sides of which are perforated. This cylinder is mounted upon a vertical spindle, and by means of wheelwork this cylinder is capable of receiving a rapid motion of revolution. Into this cylinder a charge of the mixture of the crystals with the water is introduced. When the motion commences the centrifugal force makes the contents of the vessel fly to the circumference, the liquid passes through the holes in the sides of the vessel, and the crystals of sugar form into a layer round the sides several inches thick. When the water has been expelled a little clear syrup is introduced into the vessel; this syrup passes through the sugar, and carries with it the last traces of the coloured liquid. When the motion ceases the sugar is ready for market.

The peculiar advantage of centrifugal force for this process is that each atom of water is expelled by a force which acts upon itself directly, and is not transmitted by the pressure of the surrounding particles. For example, suppose the sugar were subjected to pressure in an hydraulic press, or in some other machine adapted for the purpose; the particles of sugar on the exterior would be crushed, but the pressure would only be imperfectly transmitted to the interior. In fact, unless the crystals were so compressed together that all the interstices had disappeared, the water would still remain in the mass. If the compression could be carried to such an extent that this should be attained, it is manifest that the crystals would be crushed and disfigured. But with centrifugal force the action is quite different. When the crystals are packed as close together as possible without injury to their form, numerous interstices are left; from these the water flies by the centrifugal force of its own inertia.

It is manifest that this useful application of centrifugal force is capable of more extended utility than the single example we have given. Drying machines for cloths which are in process of bleaching depend on the same principle. The liquid flies from the interstices of the cloth in the same way as it does from those of the sugar.

PRACTICAL APPLICATION OF THE FINE ARTS.—I.

THE ART OF GLASS-PAINTING.

BY P. H. DELAMOTTE,

Professor of Drawing, King's College, London.

I.—INTRODUCTORY.

THE discovery of glass, like that of many other most useful and important inventions, is wrapped in obscurity. Not even a myth contains concealed within its kernel the origin of this valuable addition to man's comfort, as that of Prometheus reveals the source of fire. The legends told by Pliny and Josephus of pirates or Jews using blocks of soda to support their fire, and thus accidentally discovering glass, refute themselves before the light of scientific inquiry. No ordinary wood fire would thus convert sand and soda into glass. More probably miners smelting metals, noticing some vitreous remains amongst the slag, admired and imitated them; or it might be that potters saw a glaze run over some of the pottery that they were baking. But however the art originated, we know that in the early times of the Egyptian empire, before even the period usually assigned to the exodus of the Israelites, glass was made into bottles and beads, and one of the latter exists, having on it the name of a king of the eighteenth dynasty, who lived about B.C. 1500. Later on these same Egyptians manufactured vases, cups, perhaps lamps, and certainly mosaics, and understood the art of glass-cutting. Glass-blowers are portrayed at work both at Thebes and at Beni-Hassan, and Alexander the Great is said to have been buried in a coffin of glass. Glass was used for bottles for wine, some of which were enclosed in wicker-work and some in leather; but more remarkable still is the discovery in Egyptian tombs of several bottles inscribed with Chinese letters—pointing, it would seem, to an Oriental origin for this art.

From Egypt the manufacture of glass slowly spread to the other coasts of the Mediterranean, to Phœnicia, to Greece, and to Rome. The Phœnicians at an early period made some marvellous works, if we believe, as seems most credible, that the huge emerald pillars mentioned by Herodotus, as seen by him in the Temple of Hercules at Tyre, were some of those artificial gems for which the Egyptians and Phœnicians were for a long time celebrated. To Greece the art took a long time to penetrate, and but little seems to have been done by the Greeks until they had lost their independence and had come under Roman rule, when the Romans themselves were already excelling in the same line. Under the Emperor Tiberius great encouragement was given to workers in the art of glass-making, and subsequent emperors were great connoisseurs of the elegant creations in this material.

The first use of glass for windows seems to have originated soon after the period of which we have just been speaking—viz., in the first centuries of the Christian era. Seneca, who lived in the third century, is the first author who distinctly mentions such an application of the material; but a pane was found at Herculaneum, a city which we know was overwhelmed A.D. 79. Here, again, we are at a loss to know where the next step was made, of introducing coloured glass into windows, or, indeed, whether this was another step, and not one and the same. Many people, considering that it is far easier to make glass of some of the commoner colours than to produce that which is perfectly colourless and transparent, have supposed that coloured windows preceded those of clear glass. This is probably true, but the early windows were made either of glass of one colour only or of slight modifications of one colour. It was as much another stage to introduce a pattern, with distinct and contrasted colours, as it was to introduce transparent and colourless glass. Chrysostom speaks of windows of divers colours. The church of St. Sophia at Constantinople is said to have had coloured glass windows in the sixth century; but the earliest coloured windows of which we know the precise date were those made for Pope Leo III. in 795, to be inserted in the Church of St. John Lateran at Rome; and the earliest date that can be relied on at Constantinople is A.D. 949, when Constantine VII. sent his portrait, beautifully painted on glass, to Abderrahman, the Moorish monarch at Cordova, in Spain. This, of course, must have been produced by colours laid on the surface of the glass, and not burnt in; in fact, the latter improvement is attributed to either the Germans or Flemings at a much later date. The yellow stain produced by silver is said to have been the result of an accident which happened about the beginning of the sixteenth century—some say to Van Eyck, others to Fra Giacomo da Ulmo. The latter is said by Vasari to have dropped a silver button into the lime of the furnace in which he was about to burn some painted glass, and that the silver, touching the heated plates, caused a yellow discolouration, which accidental circumstance he, like a true observer, immediately turned to account.

Into Gaul the art of making and colouring glass had been introduced in the earliest centuries of the Christian era, and about the eleventh century it had begun to flourish, being advanced and nourished, like many other of the fine arts, more especially by its dedication to ecclesiastical purposes, for decorative glass does not seem to have been used in private houses until nearly the sixteenth century. Between 1399 and 1429 the hotel of the Duke of Orleans in the Rue de la Poterne les Saints Pol in Paris was adorned with coloured glass, which, however, on being at a somewhat later date cleaned and washed, required renovating and colouring afresh, so that evidently the colours were not burnt in.

Bede says that glass and glass-makers were brought to England as early as A.D. 674, but the art does not seem to have flourished greatly here, for Matthew of Paris says that in the time of Henry III. only few churches had glass windows; but after this it must have rapidly arrived at perfection, for the colours, and especially the blue, of twelfth century glass are such as have been surpassed at no subsequent period.

The process since that time has not materially altered. Slight improvements have been made, and at one time a portion of the art had been lost. This now has been recovered; but though we can trace stages of development running parallel to the different stages of architecture, there have been no great revolutions in the art down to the present day.

Having now drawn a slight sketch of the progress from the

earliest known specimens of glass down to the period at which this decorative art was practised in its greatest perfection in our own country, it is time to give some notice of how the process of painting upon glass is carried on; and here we would draw attention to the difference between stained and painted glass. Stained glass is that which is coloured in its manufacture; the painting is a shade burnt into the glass at a subsequent period, so that most windows contain stained glass painted. In the early days of painting glass, colours were simply applied with white of egg or oil, or some such convenient vehicle to the uncoloured or so-called white glass; the picture was afterwards varnished, and the whole was complete. At a later period, when the art of burning in the colours was discovered, the former process was considered insufficient, and for all works of any importance it has been discarded, and will not be further referred to by us. The present process is really the production of a species of enamel on the surface of various coloured glasses, thereby producing various degrees of transparency.

We shall now speak of the various stages that have to be passed through before a window can be put into the opening for which it is designed, and we shall do this as if the work were entirely carried through by the same individual, though any one will see at once that the labours at the furnace and the artistic manipulations are not likely to be performed by the same pair of hands in these days of minute subdivision of labour.

The first requisite is a careful design, and the circumstances of the case necessarily remove the art of designing windows both from painting and from mere mechanical designing, such as that used for ordinary art manufactures. The next step is the production of the glass itself—its colouring—and here we must note the difference of its manufacture, both from that of transparent glass used in ordinary windows, and that of coloured glass employed for ornamental purposes. We must next look to certain peculiarities of English and foreign manufacturers, and notice how brightness of light and delicacy of colouring are produced. After this the glass has to be cut to the required shapes, to be set up, and at length painted. These stages we shall describe. Then the various styles of shading, and their effects, will engage us for a short time before we follow our picture to the furnace, in which its shades and stains are indelibly fixed. After this the putting the whole together, and fixing it in its required place, will complete the work.

Our future papers on the art of painting on glass, which is one of the most interesting processes connected with the practical application of the fine arts to industrial work, will be accompanied by illustrations, which will not only be of great use and value to the student of this beautiful decorative art, but also furnish suitable studies for enlargement, to be coloured subsequently, to show the general effect of the composition when executed in painted glass.

THE ELECTRIC TELEGRAPH.—IX.

By J. M. Wigner, B.A.

THE RELAY—AUTOMATIC TELEGRAPHS—BAIN'S—WHEATSTONE'S—THE SOUNDER.

In the embossing Morse instrument described in our last, it is clear that the electro-magnet must possess sufficient power to press the style rather firmly against the riband. In the ink recorder a certain amount of pressure is likewise required. Now, we find that when the electric current has to travel over a very long circuit its power is considerably reduced, and even if we increase the battery power there is an increased resistance, so that we cannot transmit to very great distances a current sufficiently powerful to print its own messages. In shorter circuits defective insulation, and other similar causes, often prevent the message being duly recorded.

At first sight this appears a serious difficulty; but it has been met and entirely removed by a most simple but ingenious piece of apparatus called a "relay." By means of this the current arriving by the line-wire calls into action the battery at the receiving station, and this local battery is then made to print the message in its own instrument.

Many different forms are given to the relay, and one of the simplest of these is shown in Fig. 38. A bobbin (or sometimes two placed side by side) is secured to the stand of the instrument, the ends of the wire which passes round it being connected with binding-screws, situated one at each side of the instrument. The line-wire is connected to one of these and the earth-plate to the other, so that the current as it arrives merely traverses the coils, and passes on to the earth. The keeper of

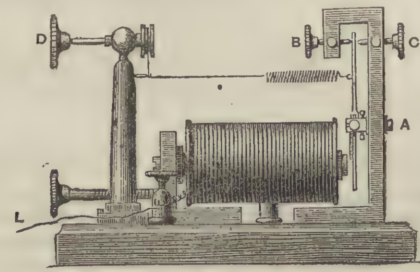


Fig. 38.

the electro-magnet is mounted on a lever which turns on a pivot at A, so as to vibrate with as little friction as possible. The upper end of this lever plays between two set-screws, B and C, by which its motion is regulated as required. A delicate spiral spring is affixed to its upper end, and keeps it, when no current is passing, resting against the tip of B, which is covered with a piece of agate or other good insulating material. The other end of the spring is connected to a cord which passes through a loop, and is then attached to a small reel moved by the milled head D. In this way it can be adjusted so as just to keep the lever pressing against B, but at the same time to allow it to yield to the faintest attraction from the magnet.

The recording instrument is now placed in circuit between C and one pole of the local battery, while the other pole is in communication with the axis A on which the lever turns. The manner in which the instrument acts will now be manifest. The circuit of the receiving instrument is interrupted between the point of C and the lever; the agate tip of B preventing any circuit through that.

Now if a current passes along the line-wire and round the bobbin, it at once converts it into an electro-magnet, and overcoming the tension of the spiral springs brings the lever into contact with C, and thus sets the recorder to work. To ensure contact, the tip of C, and the surface of the lever under it, are both covered with platinum. In this way the style moves just as it would if the current from the line-wire passed through the instrument itself, but there is sufficient power to print the message distinctly.

It will easily be seen that by means of relays suitably arranged any message arriving at a station can be actually made to retransmit itself to any other station or stations without any assistance from the clerk in charge. The telegraph thus becomes almost automatic, and we have in this an illustration of the marvels that may be accomplished by the aid of science.

A difficulty has been found to exist in very long lines, and especially in submarine cables, in the transmission of messages even with the relay, and it has been suggested to make one or two breaks in the line, and at each to introduce a relay and a new battery. The project of laying the Atlantic cable in three sections, with relay stations at Greenland and one other place, was some few years ago seriously discussed.

The greatest speed attainable with the Morse, under ordinary circumstances, is about thirty-five to forty words per minute. The hindrance, however, to a greater speed, is not in the instrument or the power of the electric current, but in the labour required for the transmission; and when we consider that on an average ten or twelve distinct signals have to be given for every word sent, we are only surprised that this extreme rate can ever be attained. The lines and instruments are, however, capable of accomplishing more than this; and hence means have been sought of increasing the speed of transmission, and thus accomplishing a greater amount of work without increasing the number of line-wires or instruments, since these add so greatly to the cost.

One plan that has been tried, especially on the Continent, consists in setting up the message in type; this is not made

on the ordinary plan, but cut out of sheet brass in such a way that the elevations in it correspond to the marks in the Morse alphabet. This type is placed on a metal tray connected with the line-wire, and is made to travel rapidly under a small spring connected with one pole of the battery. Thus at every elevation in the type a current is transmitted, the duration of which is regulated by the arrangement of the type. Fig. 39

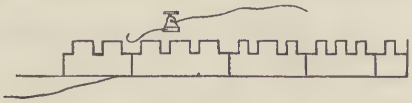


Fig. 39.

will illustrate this, the word "Morse" being here shown as set up in the type.

In this way several clerks may be occupied in setting up the messages, which may be successively transmitted at a very great speed, all of them being transmitted along one wire. The strip of paper at the receiving station must, of course, be made to move in this case at a greater speed than usual. Besides the saving thus effected, there is an additional advantage attained by setting up a message in type, and this is that the same message may easily be sent in succession along different lines. In the case, for instance, of the Queen's speech in opening Parliament, the same message has to be sent to almost every town in the kingdom, and if once set up the same type may be run through each instrument.

In this country, however, a somewhat different plan is adopted. There are, in fact, two systems of *automatic* transmission, invented respectively by Bain and Wheatstone, which have been tried. In both of these the message is punched in a strip of rather stout paper, which is then drawn through the transmitting apparatus. Bain's instrument was the earlier of the two, and was originally worked for some time on the line from Liverpool to Manchester, a speed of about seventy words per minute being attained. Difficulty was, however, experienced in procuring a perfect arrangement for punching the paper, and the insulation of the lines was likewise defective; this impeded the speed of the messages, and the use of the instruments was discontinued.

The strip of paper was punched with the same signs as those received in the ordinary way, the embossed part being removed by the punch. A strip of paper with the word "Bain" punched on it is shown at Fig. 40. When thus punctured, it is drawn

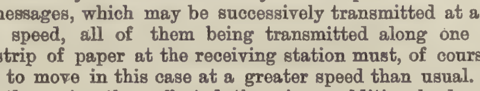


Fig. 40.

over a metallic roller connected with the line-wire, while a narrow metallic spring presses on its upper surface, and thus comes in contact with the roller wherever one of the spaces occurs. The end of this spring is usually divided into two or three prongs, so as to ensure a contact being made, and thus it will be seen currents of varying length are transmitted, just as when the ordinary Morse key is used. In the case of a long message several operators may commence punching it at different parts, and the separate strips may easily be joined together and drawn through the instrument.

In Wheatstone's Automatic Telegraph the message is likewise punctured on a strip of paper, but in a somewhat different way. Three punches are placed side by side, the middle one being rather smaller than the others. A stud for striking with the hand is connected to the head of each, and the riband is drawn under them.

The small centre punch is merely used to space out the words and letters, the one which is at the upper side being used to represent the dots of the Morse Code, and the lower one for the

Fig. 41.

dashes. The strip, when punched and ready for transmission, presents the appearance shown in Fig. 41. The word "Wheatstone" is here punched in it.

The punching apparatus used is so arranged that the paper is moved forward a small interval at each descent of a punch, and thus the proper spacing of the words and letters is attained.

The transmitting apparatus required with this strip is, like the receiver, of a special construction. Three parallel wires are made to descend at constant intervals upon the strip as it is moved onward, and the connections are so arranged that when the upper wire passes through an opening and touches the metal underneath, a positive current is transmitted, while the lower wire in like manner produces a negative current.

In the receiving instrument there is a small reservoir of ink with two minute apertures in its under surface, so small that the ink cannot flow through them. The strip is drawn under this, and two polarised electro-magnets are so arranged, that when a positive current is received one of these forces a small pointer through the right-hand aperture, and thus produces a dot on this edge of the strip; when a negative current is received, the other magnet is called into play, and produces a similar dot at the other side of the strip. The message as received then will present the appearance shown in Fig. 42. The merits of this

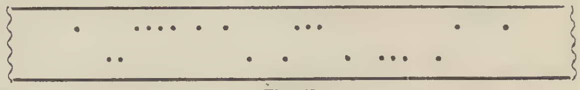


Fig. 42.

system are increased speed and greater accuracy. The punches are very easily and rapidly worked, but long-continued striking tends to render the hands somewhat tender, and hence in some cases the punches are worked by steam, and a gentle touch suffices to allow the punch to act on the paper placed under it. A single wire will with this instrument keep several punches at one end and several readers at the other fully occupied.

The Queen's speech on opening Parliament in 1871 was transmitted to many of the principal towns in England by this instrument, and in one case a speed of 94 words per minute was attained. This was between London and Bradford, and the wire was, of course, in very good condition as regards conductivity and insulation. The speech contained 1,780 words, and the length of the riband on which it was punctured was a little over 111 yards.

On the same occasion the speech was transmitted to various places by the ordinary Morse instrument, and the greatest speed attained was on the line to Brighton, the whole message being transmitted to that place in 43½ minutes, that is, at an average speed of about 40 words per minute. This is the greatest speed ever recorded as being continued for such a length of time: a few abbreviations were, however, used.

As we have already mentioned, a peculiar clicking sound is produced by the Morse instrument when at work. This is caused by the oscillating lever striking against the set-screws which regulate its play, and thus two taps are produced for every sign transmitted. When the dot is sent these taps succeed one another very rapidly, but with the dash a longer interval elapses. An unpractised ear will, of course, be quite unable to discern this, but an experienced clerk is frequently able to receive and write down the message from the sound alone, without even looking at the strip. The instrument may indeed be said to dictate it to him, and he writes it by ear.

The great advantage of this is at once apparent, but in this country it is not considered well to receive the message in this way alone. The strip is therefore always allowed to receive the message, and this can be referred to, if necessary, so as to ensure greater accuracy. In America, however, many clerks read entirely by ear, and instruments known as "sounders" are especially constructed for the purpose.

The "sounder" consists of an electro-magnet suitably mounted. Its keeper is fixed to a lever, at the other end of which is a small hammer made to play between two anvils. These are so arranged that a less intense sound is produced by the upper than by the under one, and by means of adjusting screws and a spiral spring the exact sound of each can be regulated.

This instrument is much simpler in its construction, and has in most parts of America quite superseded the other form. There is, however, one serious drawback to its employment, and that is the fact that no written record is left. It is stated however, that much fewer mistakes arise when it is employed, and that the ear is found to be much more reliable than the eye.

VEGETABLE COMMERCIAL PRODUCTS.

XXI.

MISCELLANEOUS PLANTS OF COMMERCIAL VALUE (*concluded*).

CORK OAK (*Quercus suber*).—This tree closely resembles the *Quercus ilex*, L., or evergreen oak, so well known in English shrubberies. It is indigenous to the mountainous regions of Spain, Portugal, and the south of France. It grows from thirty to forty feet high, and from two to three feet in diameter. Spain and Portugal supply the greatest portion of the cork which is used in Europe; abundant supplies are also received from the south of France at the foot of the Pyrenees, the islands of Sardinia and Corsica, and the forests of Algeria.

When this tree is about five years of age, the cork, which composes the greater part of its bark, begins to increase in a very remarkable manner. Nearly all its vegetative activity seems to be concentrated on this part, which grows unusually large, thick, and spongy. If left on the tree it becomes cracked and so deeply fissured that it is unfit for use. It is therefore removed before this happens. Its removal does not injure, but is beneficial to the tree, for if the cork is allowed to remain on its stem, the cork-oak seldom lives longer than fifty or sixty years; if, on the contrary, it is removed, the tree flourishes sometimes for upwards of 150 years. After the tree is thirty years old its cork may be removed at intervals of from six to ten years. The first crop of cork is generally inferior in quality, and is principally used for making floats for fishing nets. The crops are usually gathered in the months of July and August. Two opposite longitudinal incisions into the bark are made the whole length of the stem, and then several transverse ones about three feet apart. The bark is now beaten to separate it from the subjacent liber, and detached in cylindrical pieces by inserting under it the handle of the instrument, which is curved and made thin at its extremity for this purpose. In effecting this removal great care is taken not to injure the newly-formed suber or cork—viz., the living layer of cork beneath. After barking, the pieces of cork are slightly charred to close the pores, then loaded with weights to flatten them, and finally stacked in square masses in some dry place, where they remain for two or three months. In drying they lose about one-fifth of their weight.

Only when the trees are forty or fifty years old is the bark sufficiently matured for making good corks. This substance is valuable for bottle corks, because it is light, porous, compressible, and sufficiently elastic to adapt itself to the neck of a bottle. It can be cut into any shape, and, notwithstanding its porosity, is impervious to any common liquid. These qualities make it superior to all other substances as a stoppering for bottles, for which it is principally used. Corks are made as follows:—

The cork is first cut into slips, which by means of a gauge are made narrow or wide, according to the size of the corks or bungs ordered; these slips are then cut into squares of the required length, which are cut circularly with a knife by the hand, and thrown into a basket. Cork-cutting in Catalonia and the south of France is a branch of manual labour which furnishes a livelihood for a considerable portion of the population. Several attempts have been made to cut corks by machinery, but they have hitherto failed to supersede hand labour.

GATHERING THE BARK OF THE CORK-TREE.

Cork is largely manufactured into soles for boots and shoes. Cork legs, hat frames, mattresses, bolsters, life-preservers, and lifeboats are also manufactured from cork. Coffins were made of it by the ancient Egyptians. Many of the wealthier inhabitants of Spain have their houses lined with cork, which ensures the freedom of the rooms from damp. Cork, in thin slips, is used by entomologists as a lining to drawers and cabinets in which to fasten their insect pins. Spanish black and a black colour for painters are made from the calcined parings of cork.

The quantity of cork annually imported into the United Kingdom is about 3,000 tons. The price per ton varies from

£17 to £50, according to quality. The Spanish cork is the best, and fetches the highest price. Unmanufactured cork is admitted into England duty free. The duty on corks ready made is eight shillings per pound; corks only squared and rounded pay sixteen shillings per cwt.; and fishermen's corks two shillings per cwt.

BALSA (*Ochroma Lagopus*; natural order, *Sterculiaceæ*).—The wood of this tree, being soft and light like cork, is used for stopping bottles. The never-sinking rafts, which at the discovery of South America caused such surprise, were constructed of it, and are so still. This tree prevails along the coasts of South America and the West Indies. The silky hair of the capsule of this plant, as well as that of other species of the order, is employed for stuffing pillows and cushions.

SODA and POTASH, which occur abundantly in plants, are important articles in commerce, and the plants which yield them are therefore deserving of notice. A large proportion of the plants growing on sea-coasts contain soda, whilst inland plants contain potash. Various species of *Salsola*, especially *S. kali*, *S. Salicornia*, and *S. Kochia*, furnish the soda of commerce. The best soda comes to us under the name of barilla, which is, in fact, the incinerated ash of *Salsola kali*. This plant is carefully cultivated in the Spanish provinces of Murcia, Valentia, Carthagena, Malaga, and Alicante, which carry on a considerable trade in the article.

"The seed is sown in light soils, which are embanked towards the sea-shore, and furnished with sluices for admitting an occasional overflow of salt water. When the plants are ripe, the crop is cut down and dried, the seeds are rubbed out and preserved, and the rest of the plant is burnt in rude furnaces, at a temperature just sufficient to cause the ashes to enter into a state of semi-fusion, so as to concrete on cooling into cellular compact masses. The most valuable variety of this article is called *sweet barilla*. It has a greyish-blue colour, and becomes covered with a saline efflorescence when exposed for some time to the air. It is hard and difficult to break; when applied to the tongue it excites a pungent alkaline taste."* An inferior soda is made in France, England, Ireland, and the Shetlands, from sea-weed, and brought into commerce under the name of kelp. Large revenues are derived by the proprietors of the shores of the Scottish islands from the incineration of sea-weed by their tenants, who usually pay their rent in kelp. Carbonate of soda is now made from common salt (chloride of sodium), yet the burning of sea-weeds, etc., is still largely followed for the sake of the iodine contained in the ashes.

Potash is prepared for commerce by evaporating in iron pots the lixivium of wood-ashes; hence the name *potash*. The potash in plants is very soluble in water. If the wood-ash, which is an impure carbonate of potash, be put into water, and quick-lime be added to the solution, the lime will abstract the carbonic acid from the carbonate of potash, and form an insoluble carbonate of lime, which will be precipitated, and the potash will be taken up by the water, which will thus be rendered powerfully alkalinic. The lixivium or clear alkaline liquor thus obtained is then decanted off, and evaporated to dryness in iron pots, the residuum is calcined to remove all organic matter, and the product thus obtained forms the crude potash of commerce. The different varieties of potash are named either after the locality in which they are produced, or the route by which they arrive. Thus we have American, Russian, German, Illyrian, Saxon, Bohemian, and Heidelberg potashes. When still further purified, by additional calcination, potash is termed pearl-ash.

Potash can only be obtained abundantly in countries where there are vast natural forests, and where wood is so cheap that it only costs the labour of felling and hauling. In many parts of America, where timber is an encumbrance on the soil, it is felled, piled up in pyramids, and burned, solely with a view to the manufacture of this product.

Potash is a very considerable article of commerce. Russia produces annually over 300,000 cwt., which are exported from Petersburg, Riga, and Archangel; and from Poland, *viâ* Warsaw and Cracow: from East and West Prussia, *viâ* Dantzic and Konigsberg, vast quantities of potash are also exported. Hungary produces annually 150,000 cwt. of potash, of which 50,000 cwt. go to supply the demand in Bavaria and Saxony. The Harz district, the forests of Thuringia, and almost all parts of Germany rich in wood, supply potash. In modern times, however, it is received in the greatest quantities from Canada and the United States, *viâ* Boston and New York.

Potash is largely consumed in the manufacture of glass, porcelain, earthenware, and gunpowder; in colour and chemical manufactories; and also in dyeing and bleaching.

TINDER.—The internal spongy portion of several species of *Polyporus*, soaked in a solution of nitre, forms tinder. The principal places for the production of this fuel are, besides Hungary, Poland, and Sweden, Alsace, the country around Ulm, Nuremberg, Augsburg, and Frankfurt in Germany. Germany supplies the French, English, and Dutch markets, and Sweden the countries around the Baltic.

FULLER'S TEAZEL (*Dipsacus Fullonum*; natural order, *Dipsacaceæ*).—This plant is closely allied to the *Compositæ*, but differs in having free stamens, and a pendulous ovule. It is valuable for its large conical composite flower-heads, which have hard stiff bracts, the sharp points of which are hooked. These bracts remain after the flowers have died, and their points are so admirably adapted for raising the nap on woollen cloth, that no invention has yet been found to supersede them. Many carding machines have been introduced, but the best clothiers still prefer the teazel for finishing their cloth. For this purpose the conical teazel heads are cut up into halves and quarters, and fixed into a cylindrical frame, with the hooked bracts outwards, which frame is made to rotate over the surface of the cloth, until the little sharp hooks of the teazel have scratched up the required nap. Teazel heads, under the name of weavers' carders, are an extensive article of commerce, and cultivated in France, Italy, Holland, Germany, and the West of England. Large quantities are annually imported into the United Kingdom from Hamburg and Holland. The teazels are made up into bundles for sale to the clothiers, each bundle containing from 9,000 to 10,000 plants. In addition to our home produce, 14,022,384 teazel heads were imported in 1853.

BULRUSHES (*Scirpus lacustris*, L.; natural order, *Cyperaceæ*).—The bulrush, or bull-rush, grows along the margins of rivers, lakes, and ponds, especially in Northern Europe and the Netherlands. This plant is used in making the seats of rush-bottomed chairs; it is also in great demand among coopers, who place it between the staves of casks intended to hold liquid. The pithy structure of the rush induces the swelling of the culm, and the interstices between the staves are thus closed, and the cask rendered water-tight. Many vessels laden with this rush arrive annually in England from Holland and Belgium, bringing thirty or forty tons of rushes each voyage. This is a very large quantity, considering the lightness of the material. More than 1,000 tons of bulrushes are annually imported into the United Kingdom.

SOFT RUSH (*Juncus effusus*, L.; natural order, *Juncaceæ*).—The pith of the common soft rush, as also that of *Juncus conglomeratus*, is employed for making the wicks of rush-lights, which continue to be used, although not so much as formerly.

In Japan, the manufacture of mats, etc., from rushes, is a regular trade. The floors of their houses are covered with rush mats of great beauty and variety, and rush mats are the only carpets and beds used by the Chinese. A light sort of matting made of the same material is used as a window blind. The sugar sent home from the East Indies is packed in bags made of rush-matting. The size of the Japanese rush mats appears to be regulated by law, for they are all of the same magnitude throughout the kingdom, the only exception being the mats in the imperial palace at Jeddo. Rushes are also used for chair bottoms and baskets.

DUTCH RUSH (*Equisetum hyemale*, L.; natural order, *Equisetaceæ*).—Used for polishing hard woods, alabaster, marbles, and other substances, for which purpose it is well adapted, by the large quantity of silex which is contained in its cuticle. The invention of sand and emery papers in modern times has, however, now almost superseded this natural polisher. It is still much used in Holland, where it grows abundantly in low boggy ground; it is found in damp woods in this country, but is occasionally imported from Holland.

BAST (*Tilia Europœa*; natural order, *Tiliaceæ*).—The common linden or lime-tree is easily recognised by its obliquely cordate, unsymmetrical leaf, and the curious bract to which the peduncle or flower-stem adheres. In Northern Europe and

* "Ure's Dictionary of Arts, Manufactures, and Mines," vol. iii., p. 500. 1867.

Russia, bast mats, ropes, and twines are made from the inner fibrous bark of this tree. At the proper season the stems are cut longitudinally, and the bark is taken off in long strips. The outer bark is easily separated from the inner; and the latter dried constitutes the bast of commerce. This is plaited by the Russians into mats from a yard and a half to two yards square, which are much used by gardeners and upholsterers. These mats are also employed for lining the holds of vessels intended to receive corn. Not fewer than 14,000,000 are annually imported into the United Kingdom from various Russian ports, but chiefly from Archangel.

AGRICULTURAL CHEMISTRY.—VIII.

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CHAPTER VIII.—NITROGENOUS MANURES.

THE most valuable kinds of manures at present employed are those which, owing to the large amount of nitrogen which they contain, are termed nitrogenous. In this chapter we propose to describe the more important fertilisers which act chiefly by means of their nitrogen, but some of which are also more or less useful on account of the phosphates and alkaline salts which they contain.

Peruvian guano is the most generally employed nitrogenous manure. The term "guano" is a corruption of the Peruvian (Indian) word *huano*, signifying dung. During countless ages this manure has been employed in Peru, and in such high estimation was it held, that any person detected in the act of killing the sea-fowls whose dried excreta constituted this manure, was liable to be punished by death. We need not feel surprised at the protection afforded to the guano-producing birds, when we learn that large tracts of country would have remained unproductive were it not for the liberal application of guano to their soils.

In Peru rain is a rare phenomenon, and the temperature is very high. The conditions for the preservation of the excreta of birds are therefore most favourable in this climate. Countless sea-fowls frequent the isles and rocky promontories of the coasts, and their excrements are rapidly dried, and in a manner baked immediately after being voided. The dried excreta is to a large extent soluble in water; but in Peru there is no rain to wash away the soluble ingredients of the guano, and consequently little save water is lost by evaporation or solution. In other countries, where bird-manure accumulates in certain places, the rain washes away the greater portion of the alkaline salts, whilst by fermentation, induced by the united influence of moisture and heat, a portion of its nitrogen escapes in the form of ammonia, and the rest is perhaps altogether washed away by rain.

Peruvian guano contains large proportions of ammonic urate, oxalate, and phosphate, various alkaline salts (compounds of the metals sodium and potassium with acids and chlorine), calcic phosphate, and organic matter. Until recently an average sample of Peruvian guano had the following composition per 100 parts:—

Moisture	12
Nitrogenous organic matter and ammoniacal salts	56
Yielding ammonia	(16)
Tricalcic phosphate (tribasic phosphate of lime)	22·5
Alkaline salts	9
Insoluble mineral salts	0·5
	100·0

As the annual importations of Peruvian guano into these countries amount to hundreds of thousands of tons, and as three-fourths of its value (when of good quality) are due to its nitrogen, the proportion of that ingredient in a sample of guano is a matter of prime importance to the purchaser of the article. The importations during some recent years have, however, been of a most variable character, although formerly no manure possessed a more constant composition than Chinchas Islands (Peruvian) guano. In very few samples has the per-centage of ammonia* risen to 16, whilst in many but 9 per cent. of this constituent has been found. The importers of Peruvian guano refuse to guarantee the presence of any particular amount of ammonia; hence the purchasers of this once standard manure are liable to pay £12 or £13 for an article that may not be actually worth £9.

* 14 parts of nitrogen are equivalent to 17 parts of ammonia. In guano only a portion of the nitrogen exists in the form of ammonia; the rest is a constituent of uric acid and other nitrogenous bodies.

Peruvian guano is frequently largely adulterated with clay, plaster of Paris, ochre, and inferior phosphatic guanos. We have often examined Peruvian guano containing from 30 to 60 per cent. of fraudulently added earthy or other useless matters. When genuine and of good quality, this kind of guano has a light brown or greyish colour. It consists of powder commingled with hard lumps, which on being broken exhibit a lighter colour and a crystalline appearance. A bushel of good guano weighs about seventy pounds, whilst adulterated kinds often weigh more than a hundred pounds per bushel. A rough test of the purity of the article is to burn three-quarters of an ounce of the suspected sample upon a piece of tin or iron placed on a clear fire. If the residue be not more than a quarter of an ounce, the guano is probably pure; but if the residue amounts to half an ounce, the sample is either extremely inferior, or grossly adulterated. Guano adulterated with ochre or clay has usually a dark-brown colour, and it is much colder to the touch, and feels heavier than good Peruvian guano.

Peruvian guano is largely used as a manure for cereals; it is also commonly applied to green crops, but superphosphate of lime is more generally used for the latter. A mixture of two parts of superphosphate of lime and one of Peruvian guano usually gives good results when applied to mangolds, turnips, and other root-crops. The best results follow the use of this manure when it is applied to heavy clays containing but little organic matter; light soils, on the contrary, appear to be more benefited by the application of phosphatic manures.

Sal-ammoniac, or ammonic chloride, and ammonic sulphate, are very valuable nitrogenous manures; indeed, it is probable that it is their ammonia alone which is useful to plants. When coal is submitted to what is termed destructive distillation, for the purpose of preparing illuminating gas, the small proportion of nitrogen which the fuel contains unites with part of the hydrogen, and forms the gas termed ammonia. The gases evolved from the highly-heated coal are passed through water, which dissolves nearly all the ammonia, and some tarry matters, carbonic acid, and sulphuretted hydrogen. The water saturated with these matters is termed gas liquor, or ammoniacal liquor, and it is the source of nearly the whole of the ammonia and ammoniacal salts manufactured in the United Kingdom. This liquor is put into large tanks, and heated by steam-pipes. The ammonia is driven off, and forced into vessels containing either sulphuric acid or muriatic acid (chlorhydric acid). The acid and ammonia unite, producing a sulphate or muriate, as the case may be. The solution of the ammoniacal salt is next boiled down, and the salt crystallised.

Commercial ammonic sulphate contains about 25 per cent. of ammonia, and sal-ammoniac 30 per cent. of ammonia. In the former salt there is sometimes present a salt termed sulphocyanide of ammonium, which is poisonous to plants. The presence of this compound may be detected by adding to a solution of the ammonic sulphate a few drops of solution of ferric chloride or sulphate (perchloride, or persulphate of iron) which has the effect of producing with the sulphocyanide of ammonium a deep red colour.

The ammoniacal salts supply nitrogen to plants, and these are most efficacious when applied to the cereals and the natural grasses. The leguminous crops are not always benefited by the application of ammonia salts.

Gas liquor, diluted with four times its bulk of water, may be employed as a liquid manure. It is an excellent addition to the compost heap. Gas lime (the refuse lime, containing certain impurities derived from coal gas) is held in high estimation as a manure, but we believe it to be seldom worth the cost of its carriage from the gas works to the field. It contains only a trace of ammonia, and it is merely the lime of which it is mainly composed that renders it at all useful.

Soot is used largely for manurial purposes. It consists of carbon (charcoal), salts of ammonia, gypsum, and other minerals, and various organic bodies. The amount of ammonia varies from 1 to 6 per cent. This manure is used chiefly as a spring top-dressing to pastures and meadows. Dried blood, hair, leather clippings, feathers, horn shaving, shoddy, and

woollen rags are used for manurial purposes. They contain about a sixth part of their weight of nitrogen; but with the exception of dried blood, they decompose extremely slowly in the soil. Shoddy and woollen rags may be rendered immediately available by steeping them in strong sulphuric acid for a few days. Their decomposition may also be hastened by incorporating them with a compost in a state of active fermentation. The artificial manure manufacturers often use these articles as cheap sources of nitrogen, but for this purpose they are not nearly so valuable as ammonic sulphate, guano, or blood.

Rape-cake, at one time used exclusively as a manure, is now largely employed as a food for stock. It decomposes readily enough in the soil, and its action is seldom felt after the first year. In every 100 pounds there are about 6 pounds of nitrogen, $2\frac{1}{2}$ pounds of phosphoric acid, and 2 pounds of alkaline salts. It is chiefly used as a manure for wheat, and may be either drilled in with the seeds or applied as a top-dressing in the spring.

Sodic nitrate (nitrate of soda or cubic nitre) is one of the best top-dressings applied to the cereals; under its influence the sickly yellowish colour which growing wheat sometimes assumes is generally changed into a healthy green. Commercial sodic nitrate contains about 17 per cent. of nitrogen, somewhat less than is yielded by ammonic sulphate.

Before being applied, sodic nitrate should be mixed with three or four times its weight of ashes, common salt, or some such material, and it should be applied as equably as possible to the soil. These observations apply equally to all the concentrated manures. When sodic nitrate is pure it evolves, when thrown into the fire, a fine yellow light; but if adulterated with common salt, the colour is greenish-yellow. Dry sodic nitrate contains 63·53 per cent. of nitric acid, which is expelled from the salt at a red heat. If an ounce of the nitrate does not lose by prolonged ignition nearly two-thirds of an ounce, it indicates some such adulterant as sodic sulphate (Glauber salts) or common salt.

PRACTICAL PERSPECTIVE.—IX.

The object of this lesson is to show the method of putting into perspective an object when placed at an angle to the picture, *and at a distance from the foreground.*

Let us, in the first place, recapitulate the method of projecting the object when one of its angles touches the picture-plane.

In Fig. 44 B C E D is the plan of the cubical figure which is to form the subject of the lesson.

Having drawn the picture-line, horizontal line, and line of direction, and having fixed the station-point S, construct at S the angles G S H and I S J equal to the angles C B E, D B F in the plan, and produce the lines S G and S I to meet the horizontal line in VP1 and VP2 (the last-named point is not shown in the figure); from VP1 and VP2, with radius extending to S, describe arcs cutting the horizontal line in MP1 and MP2.

Now at B′ (the distance of the nearest angle of the object on the right of the spectator) erect a perpendicular B′ F, equal to the height of the object, and from B′ draw lines to the vanishing-points; set off on the picture-line the lengths B′C and B′ D′ equal to B C and B D on the plan, and draw lines to the measuring-points. These lines will, as already shown, cut those drawn to the vanishing-points, and thus give the positions of the edges, which will stand perpendicularly on the points C and D in the plan.

From F draw lines to the vanishing-points, and then the perpendiculars *c* and *d* will complete the projection of the object.

We now proceed to delineate the object when placed on the left of the spectator and within the picture (Fig. 45).

It will, in the first place, be necessary to find the points of distance, and it will be remembered that these are at the same distance from the centre of the picture as S. Therefore from C, with radius C S, describe a semicircle, cutting the horizontal line in the points PD1 and PD2.

Now find the vanishing-points and measuring-points. In the present case these are the same as have been used in Fig. 44.

In the first instance, mark the point *b*, which would be the situation of the front edge of the object if it were in the immediate foreground.

Now, as the object is to be moved directly backward, it will travel in a line at right angles to the picture-plane, and such a line will vanish in the centre of the picture. Therefore—

From *b* draw a line to C, and

From *b* set off *b x*, representing the distance which the object is supposed to be within the picture; and from *x* draw a line to the point of distance, cutting *b* C in *b*′.

Through *b*′ draw a horizontal line, called the *movable base-line*, and this, in the actual working of the subject, will take the place of the picture-line.

Now on each side of the point *b* on the picture-line set off the real length of the sides, as per plan—viz., *b c* and *b d*—and from these points draw lines to the centre of the picture, cutting the movable base-line in *c*′ and *d*′. The movable base-line is thus divided proportionately to the corresponding portion of the picture-line,* and now the work can proceed in a manner precisely similar to that in Fig. 44

From *b*′ draw lines to the vanishing-points, and from *c*′ and *d*′ draw lines to the measuring-points, cutting these in *c*″ and *d*″.

At *b*′ erect a perpendicular for the front of the object; but the question now arises, how to cut this off at the required height, for, of course, as it is in the distance, the real height will be diminished, but how much? Now it will be remembered that the whole object has moved backward in a direct track from the point *b* in the foreground. Therefore draw at *b* a perpendicular of the true height of the object—viz., *b f*—and from *f* draw a line to the centre of the picture, cutting the perpendicular *b*′ in *f*′.

Then *b*′ *f*′ is the perspective height of the front perpendicular of the object, for it will be seen that it is a portion of a plane standing in the line from *b* to C, and bounded at the top by the line *f* C.

From *f*′ draw lines to the vanishing-points.

At *c*″ and *d*″ erect perpendiculars, meeting these, and giving the perspective height of the edges *c* and *d*.

From the upper extremities of these draw lines to the vanishing-points, which will complete the projection.

Exercise 33.

The scale to be $\frac{1}{4}$ inch to the foot; the height of the spectator, 6 feet; his distance, 18 feet.

Put into perspective a cubical figure, 4 feet square at base and 9 feet high, when its left side recedes from the picture-plane at 40°, and its nearest angle is at 6 feet on the left of the spectator.

Exercise 34.

Put into perspective the same object when it is at 8 feet on the right of the spectator, and 10 feet within the picture.

Fig. 46.—The subject of this lesson is a square block or plinth, on which rests another square block of smaller size, thus leaving a ledge or step all round.

The height and distance of the spectator having been duly arranged, and the width and position, A B, of the object having been marked, draw lines from A and B to the centre of the picture.

From B draw a line to the point of distance, cutting the line A C in C′.

From C′ draw a horizontal line, cutting the line B C in D.

A C′ B D is then the plan of the plinth.

This figure will be seen to contain one diagonal, B C′. Draw the second, A D.

It is now necessary to draw within this plan the plan of the upper block; that is, to show where the upper block would stand if it penetrated the plinth and touched the ground.

From A mark off E, and from B mark off F, each of the lengths A E and B F being equal to the distance which the plinth projects beyond the upper block; that is, the width of the ledge or step all round.

From E and F draw lines to the centre of the picture, cutting the diagonals in *e g* and *f h* respectively.

Join *e f h g*, and the figure thus formed will be the plan of the upper block.

Now, as the upper block stands back from the plan of the picture, it will be easily understood that the perspective height will be different from the *real* height, and therefore it becomes necessary to erect in the immediate foreground a perpendicular, on which all heights are marked, and from which their apparent

* See "Practical Geometry Applied to Linear Drawing," Fig. 2. (Vol. I., p. 64).

heights are obtained. This perpendicular is called the *line of measurement.*

To obtain this, draw a line from C, passing through the intersection *i* of the diagonals A D, B C′, and meeting the picture-line in L.

At L erect the required perpendicular, of indefinite height.

These preliminaries being settled, erect perpendiculars from each of the angles A, B, C′, D.

On the line of measurement mark off L *j*, the height of the

Now it will be seen that the line drawn from the centre of the picture, through *i* in the ground-plan, passes through *e f* in *k*, which point is immediately under *k′*. Therefore a perpendicular raised from *k* should, if the work has been correctly done, pass through *k′*, and this line represents the plan or surface of the smaller block.

Now on the line of measurement set off L′, the real height of the upper block, and from L′ draw L′ C, cutting the perpendicular *k k′* in *l*.

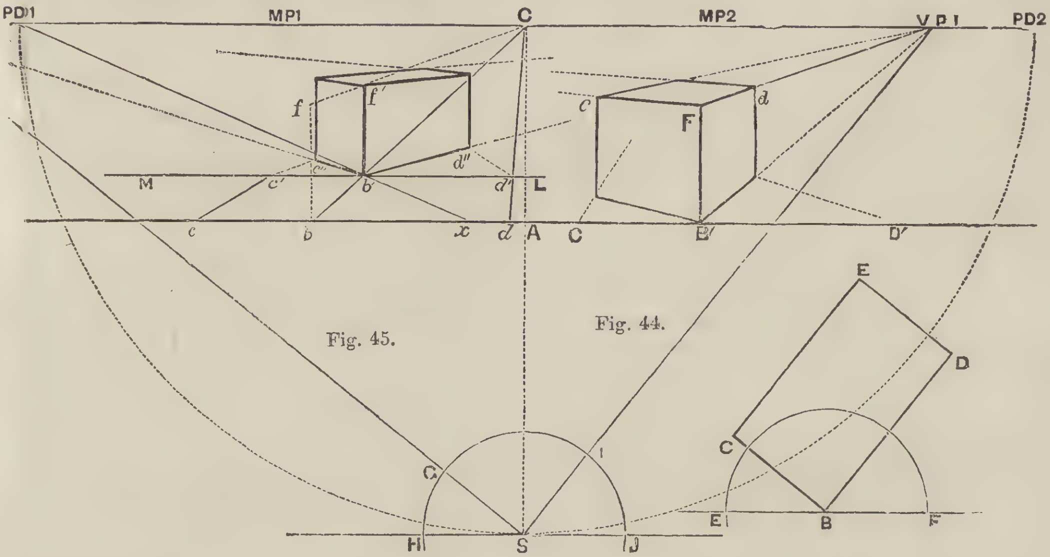


Fig. 45.

Fig. 44.

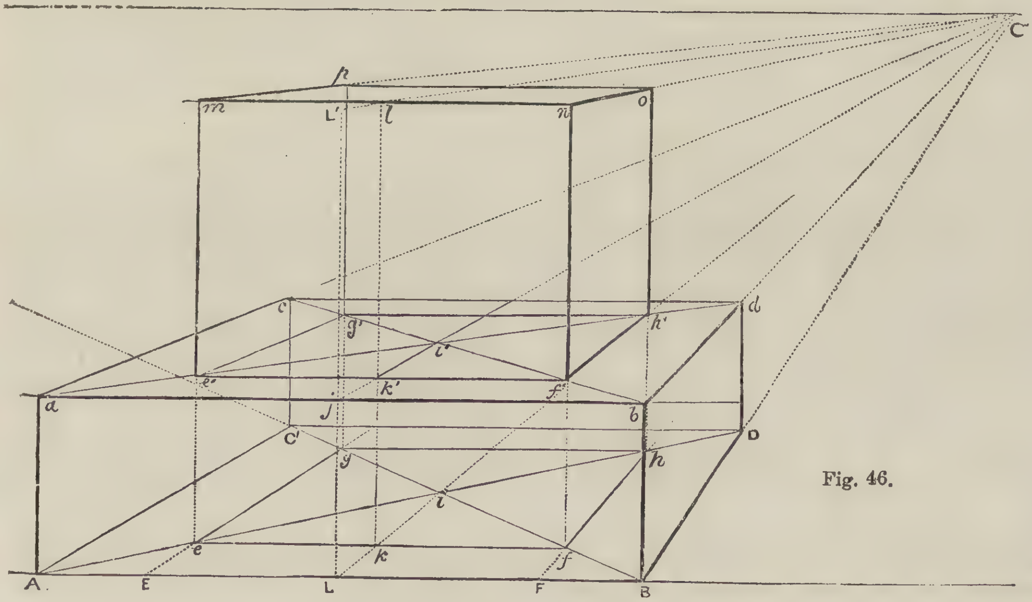


Fig. 46.

plinth; through *j* draw a horizontal, cutting the perpendiculars A and B in *a* and *b*; the horizontal *a b*, thus obtained, will be the upper edge of the front of the plinth.

From *a* and *b* draw lines to C, cutting the perpendiculars C′, D in *c* and *d*. Join *c d*, which will complete the plinth.

On the upper surface of the plinth draw the diagonals *a d* and *b c*.

From the points *e, f, g, h* (the angles of the inner figure) in the plan erect perpendiculars, cutting the diagonals *a d* and *b c* in *e′, f′, g′, h′*.

Join these points, and from *j* on the line of measurement draw a line to C, cutting the line *e′ f* in *k′*.

Through *l* draw a horizontal, cutting the perpendiculars *e* and *f* in *m* and *n*.

The rectangle *e′ m n f* is then the front of the upper block.

From *m* and *n* draw lines to C, cutting the perpendiculars *g* and *h* in *p* and *o*. Join these points, and the figure will be completed.

From the nature of the lessons which have been already given in this important subject the student will have learnt the necessity of proceeding with zealous care from step to step, so as to insure accuracy in his work. It is better to repeat every measurement twice, if not thrice, before proceeding to work from or by any point or line thus obtained, as a single false

step, involving even a very minute error in distance or position, may prove the means of rendering a great deal of otherwise carefully bestowed labour useless, and compelling the learner to cancel the faulty drawing and begin another.

Another point to be insisted on in writing a description of the method adopted in working out any problem or exercise is an accurate and careful rendering of the lines and points of measurement, shown in the figure by letters, and a rigid adherence to the letter or letters by which each point or line is known when once fixed. Although it is not absolutely necessary, it is better always to designate a line by *two* letters, namely, those assigned to the points which are its extremities, an angle as well as a triangle by *three* letters, and a parallelogram or trapezium by *four* letters, taking care in the last-named case that the letters of the corners read in regular order round the figure in either direction, as B, D, E, C, or B, C, E, D, in the plan in Fig. 44, and not B, D, C, E, or B, C, D, E, as is frequently but inaccurately written by students.

SEATS OF INDUSTRY.—XI.

DUNDEE.—I.

BY WILLIAM WATT WEBSTER.

THERE are few towns in Europe that owe their importance and prosperity so largely to the cultivation of one branch of manufacture as the town of Dundee, the chief seat of the linen trade in Scotland, and, although both sides of the Atlantic were to be searched for parallels, it would not be easy to find many instances of towns that have made more rapid progress. How the Scotch linen trade came to be concentrated to so large an extent in Dundee is a question that has often been asked, but never satisfactorily answered. Frequent and persevering efforts were made to establish various industries in the town, previous to the time when the manufacture of the coarser descriptions of linen cloth became the staple trade of the place, but they all sooner or later ended in failure. Linen manufacture is the only industry of any magnitude that has been permanently successful in Dundee, and it seems to have been adopted simply as one among the many experiments that were tried. Commenting on the "wonderful progress" of the linen manufacture in this town, Mr. M'Culloch says, "Something must be ascribed to the convenient situation of the port for obtaining supplies of raw material; and more, perhaps, to the manufacture having been long established in the towns and villages of Strathmore, the Carse of Gowrie, and the northern part of Fife, of which Dundee is the emporium. But these circumstances do not seem adequate to explain the superiority to which she has recently attained in that department; and, however unphilosophical it may seem, we do not really know that we can ascribe it to anything else than a concurrence of fortunate accidents." Of course, the chance theory is no explanation, but merely an ingenious method of stating that our information regarding the early history of the Dundee linen trade is not complete and perfect enough to furnish a solution of the problem. The enterprise of the inhabitants ought, however, to be considered among the causes of the extraordinary prosperity of the town, and a brief sketch of its history and growth will show this influence at work in the periods when its progress was most marked.

The name Dundee is said to be derived from *Don Dei*, a corruption of *Donum Dei*, and to have been conferred on the town in commemoration of the extraordinary escape from shipwreck of Prince David, Earl of Huntingdon, not far from the mouth of the Tay, on his return from the Crusades, in the year 1189. Previous to that date the town was called *Alectum*, or *Ail-lec*, which in the Gaelic tongue signifies "pleasant," or "beautiful." *Taodunum*, the "hill or fort on the Tay," was the name bestowed upon their settlement in this quarter by the Romans, who, it is recorded, were so struck by the resemblance between the river and their own "father Tiber" when they first approached it, that they exclaimed "*Ecce Tiber!*" There is a tradition that about the year 834 a British force having encamped on Tothelbrow, in the parish of Strathmartine, and the Scottish army, under Alpine, having occupied Dundee Law, a hill on the north side of the town, about 525 feet above the level of the Tay, a battle was fought in the intervening plain, which resulted in the defeat of the Scots and the capture and execution of their king. It was not till the accession of William the Lion, in 1165, that Dundee was incorporated as a royal burgh, but it had enjoyed many privileges before that date, and must have been a town of no small consequence. Traces of fortifications have been observed on the summit of Dundee Law, which are believed to have been erected by Edward I., who twice sacked and burned the town, in 1296 and in 1303, and by whom its ancient records were destroyed. It was recovered, however, by Wallace and Bruce, in 1297, and by Bruce in 1313, and at the latter date the old castle was demolished. Dundee was again burned to the ground by the Duke of Lancaster, in 1385, and it suffered a similar fate in the reign of Edward VI., when the English held possession of Brough Tay Castle. George Wishart preached the principles of the Reformation here during the plague, in 1544, from one of the gates of the town, which served to separate the uninfected from the infected, the archway of which is still standing. Through Wishart's teaching and the influence of James Halliburton, one of the earliest and ablest of the Scottish Reformers, and a native of the place, Dundee was the first of all the Scottish towns to renounce Popery, and openly profess the reformed religion. It is worthy of mention that dramatic representations, in which the vices and absurdities of the priests were ridiculed, were among the means resorted to by the earlier Reformers to wean the affections of the people of the town from the Roman Catholic Church. Two brothers of the name of Wedderburn were conspicuous among the writers of these polemical plays, one of whom was vicar of Dundee, and they are also remembered as the authors of "Gude and Godly Ballads," a series of songs devoted to the same cause. A third brother is said to have "turned the tunes and tenors of many profane songs into godly songs and hymns, whereby he stirred up the affections of many;" and it has been suggested that these were the tunes referred to by Burns, as "Dundee's wild warbling measures." But the adhesion of the inhabitants to the solemn league and covenant brought severe disaster to the town, for the Marquis of Montrose, in 1645, burned and plundered it. Dundee, however, suffered still more from Cromwell than it did from Montrose, for its citizens having refused to surrender to his authority, the Dictator sent General Monk against it. A gallant resistance having been made, Monk stormed the town, killed about a thousand soldiers and inhabitants, and afterwards plundered and burned the place. Each soldier in the victorious army had nearly £60 sterling as his share of the booty; but none of them were destined to enjoy any portion of the treasure, for the sixty vessels containing it were totally wrecked on their way to England. This was the last great disaster that Dundee sustained, and since that date it has made steady progress, nor has its subsequent history been marked by any extraordinary event.

It is not known when the linen manufacture was introduced into Dundee, but it was doubtless carried on there at a very remote period, although only on a small scale. Several highly interesting references are made to linen in ancient Scottish records, and it would appear that the dressing, spinning, and weaving of flax was a part of the general domestic work of the people for many centuries. It is mentioned that at the battle of Bannockburn, in 1314, "carters, wainmen, lackeys, and women put on shirts, smocks, and other white linens, aloft upon their usual garments, and bound towels and napkins on their spears, staves, etc." The rental lists of the Marquis of Huntly show that in 1600 rent was sometimes paid in linen; and an Englishman, who made a tour in the Highlands of Scotland about the year 1618, states that the master of the house, whether laird, farmer, or cottar, "will wear no shirt but of the flax that grows on his own ground, or of his wife's, daughters', or servants' spinning."

Towards the close of the sixteenth century, linen goods were among the principal exports from Scotland, and were sent both to England and to foreign countries. Between 10,000 and 11,000 persons were said to have been employed in Scotland about this time in making linen for the English market. Unfortunately, the Scottish Parliament passed a law prohibiting the importation of woollen goods from England, and this policy led to the prohibition of Scotch linen by the English Parliament, which for a time completely ruined the linen trade of Scotland. In 1686 the Scottish Parliament passed a curious law, entitled an "Act for Burying in Scotch Linen," in which it was decreed that "hereafter no corpse of any persons whatsoever shall be buried in any shirt, sheets, or anything else,

except in plain linen or cloth of hards, made and spun within the kingdom, without lace or points." The duty of receiving and recording certificates that bodies had been buried as directed devolved on the parish minister, and severe penalties attached to breaches of the Act. In 1693 another Act was passed, "anent right measuring and making of linen cloth," and ordaining that seals be put on every piece or half-piece, as a proof that it was the right length, breadth, and quality. The Union gave a great impetus to the linen trade of Scotland, the duties on linen goods exported to England having then been abolished, and the colonial markets opened for Scotch manufactures. At this period some 1,500,000 yards of the coarser kinds of linen cloth were annually manufactured in Scotland; and in 1720 the linens exported to England alone were valued at £200,000. Seven years later a board was established to promote and encourage the manufactures of Scotland, which had a powerful influence in developing the linen manufactures of Dundee. The incorporation of the British Linen Company, at Edinburgh, in 1746, was also a great event in the history of the Scotch linen trade. This company imported flax, linseed, and potash, which were sold on credit to respectable manufacturers, and it bought back the yarn and linen they made at fair prices. The British Linen Company also advanced money to the manufacturers on exceedingly reasonable terms, the original subscribers not having entered upon the enterprise with the view of making gain, but simply in order to further the welfare of the linen trade.

The linens manufactured in Scotland were described by a writer in the "Gentleman's Magazine," in 1742, as "the poorest and meanest;" but at that time Dundee was more celebrated for its "plaiding," a coarse woollen cloth, than for its linen. This was one of the trades that flourished for a season in the town. It was about the year 1747 that the manufacture of the linen cloth known as Osnaburg became the staple trade of Forfarshire, and especially of Dundee. In the year 1789 no less than 3,181,990 yards of coarse linen cloth, valued at £80,587, were manufactured and stamped for sale in the parish of Dundee; and 700,000 yards of sail-cloth, considered superior to that produced at Belfast, and estimated at a value of £32,000, were made within the precincts of the town. The spinning of coloured sewing thread was also at this time, and had for several years previous been an important branch of industry in the place, it having at one period been prosecuted by seven different companies or firms, maintaining an aggregate of 66 twisting-mills, employing some 1,340 spinners, and turning out annually about 270,000 pounds of thread, valued at upwards of £33,500. In 1790 a spirited attempt was made to add the spinning of cotton to the manufactures of Dundee. Seven cotton-spinning companies were started within a short time, and continued in operation for some years, but never succeeded in making the trade remunerative. Till the year 1790 all the yarn used in Dundee was spun by hand, and chiefly by people in the surrounding country districts, and the larger portion of it continued to be supplied in this way till about 1830, when spinning-machinery came into general use. A mill for spinning yarn by machinery driven by water power, erected in 1790, by Messrs. Ivory and Co., at Kinnettles, Forfarshire, was an important improvement, and three years afterwards a still more important, though not immediately successful, experiment was made, when Messrs. Fairweather and Marr built a small spinning-mill at Chapelside, the machinery of which was propelled by a ten-horse-power steam-engine. This latter mill, and another steam-power mill started shortly after it, were kept working for some time, and then stopped, but only to resume again after an interval. There were 5 steam spinning-mills, with an aggregate of 60 horse-power, and 2,000 spindles, in operation in the town of Dundee in 1798, the largest of which was the Bell Mill, erected at a cost of £17,000. The wars of Napoleon, in the early years of the present century, paralysed the linen trade of Scotland, and in 1811 there were only two spinning-mills at work in Dundee; but after the battle of Waterloo the trade revived, and by the year 1822 there were no fewer than 17 steam spinning-mills, containing 7,944 spindles, driven by engines with an aggregate of 178 horse-power, and employing about 2,000 persons, in operation in the town, while in its immediate neighbourhood there were 32 spinning-mills, containing 6,978 spindles, at work. Ten years later the steam spinning-mills in Dundee and the surrounding district were driven by engines representing a total of 800 horse-power, and employed about 3,000 persons, while the yearly consumption of flax was 15,600 tons, and the capital invested in machinery amounted to £240,000. By 1846 the number of steam spinning-mills had increased to 36, containing 71,670 spindles, and driven by engines with an aggregate motive power equal to 1,242 horses. From "Dawson's Abridged Statistical History of Scotland," published in 1853, we learn that there were in 1850 in the town and the immediate vicinity of Dundee "47 spinning-mills, with steam-engines of an aggregate of 2,075 horse-power, and 8 power-loom factories, possessing 235 horse-power and that these establishments employed in the various occupations 3,240 males and 8,142 females. "It has been ascertained," this account continues, "that the money wages distributed among this large body of individuals amounts to about £3,900 per week; the payment to the male operatives being on the average 9s. 6d., and to females 6s. weekly. Besides the power-loom factories, the town possesses 62 establishments of one kind or other using hand labour; and in these there are 4,200 looms. Add to these, 10 establishments for finishing, calendering, and packing the cloth which is produced, and we have an idea of the vigour with which the linen trade of Dundee is conducted." Since that period from 600 to 700 additional power-looms have been started. A few statistics relating to the linen and jute trade in 1867 will illustrate the astonishing progress made by the Dundee manufacturers between 1850 and that date; and since 1867 the trade has been still further developed. It was estimated that in 1867 the capital invested in factories for the spinning and manufacture of flax and jute in the town of Dundee amounted to £2,500,000, in the district to £2,200,000, and in other parts of Scotland to £1,000,000; giving a total of £5,700,000. The yarn spun in the town during the same year was calculated to amount to 31,000,000 spindles, representing a value of £3,487,500; and in the surrounding district 29,000,000 spindles were produced, valued at £3,262,500, giving a total for Dundee and its dependencies of 60,000,000 spindles, representing £6,750,000. The cloth manufactured by the 8,000 power-looms in the same year, calculated at an average of 200 yards per week for each loom, would amount to about 83,200,000 yards, or 47,272 miles. Mr. Warden, the author of "The Linen Trade," states that about 50,000 persons are employed in the linen and jute trade of Dundee. It was in 1821 that the first attempt was made to introduce power-looms in Dundee, but the experiment was not successful till fifteen years later. Messrs. William Baxter and Son built a mill at Lower Dens, intended for 90 power-looms, but they did not at that time carry out their design. In an account of Dundee written in 1833, it is stated that "power-looms have not been employed here, or, at least, not to any advantage, and they are understood to be entirely laid aside." The first power-loom factory erected in Dundee was built in 1836, at Upper Dens, by Messrs. William Baxter and Son, and soon after three others were erected, but a considerable time elapsed before any increase took place. It was only gradually that the power-loom came to supersede the hand-loom, and the latter has not even now been entirely discontinued.

PRINCIPLES OF DESIGN.—XV.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

WALL DECORATION

In this chapter we must devote ourselves to the consideration of wall decoration, or to the manner in which ornament should be applied to walls with the view of rendering them decorative.

It will appear absurd to say that all ornament that is applied to a wall should be such as will render the wall more beautiful than it would be without it; but this statement is needed, for I have seen many walls ornamented in such a manner, that they would have looked much better if they had been perfectly plain, and simply washed over with a tint of colour.

To ornament is to beautify. To decorate is to ornament. But a surface cannot be beautified unless the forms which are drawn upon it are graceful, or bold, or vigorous, or true, and unless the colours applied to it are harmonious. Yet how many walls do we meet with even in good houses—walls of corridors, walls of staircases, walls of dining-rooms, walls of libraries, and, indeed, walls of every kind of room—which are rendered offensive, rather than pleasing, by the decorations which they bear.

A wall may look well without decoration strictly so called, and this statement leads me to notice the various ways in which walls may be treated with the view of rendering them beautiful.

A wall may be simply tinted either with distemper colour, or oil colour "flatted." Distemper colour gives the best effect, and is much the cheapest, but it is not at all durable. Every mark will show upon it; if rubbed, it is marked; and it cannot be washed. Oil colour when flatted makes a nice wall, whether "stippled" or plain, and is both durable and washable. An entire wall should never be varnished.

I say that a wall can look well even if not decorated. Let me give one or two instances; but, perhaps, I had better give treatments for the entire room, including the ceiling, and not for the wall simply.

A good effect of a very plain and inexpensive character would be produced by having a black skirting, a cream-colour wall (this colour to be made of middle chrome yellow and white, and to resemble in depth the best pure cream), a cornice coloured with pale blue of greyish tint, with deep blue, white, and a slight line of red, and a ceiling of blue of almost any depth. The ceiling colour to be pure French ultramarine, or this ultramarine mixed with white and a touch of raw umber, and the cornice blues to be made in the same way. The red in the cornice to be deep vermilion if very narrow (one-sixteenth of an inch), or carmine if broad.*

A room of a slightly more decorative character would be produced by making the lower three feet of the wall of a different colour (by forming a dado) from the upper part of the wall: thus, if the other parts of the room were coloured as in the example just given, the lower three feet might be red (vermilion toned to a rich Indian red with ultramarine blue) or chocolate (purple brown and white, with a little orange chrome); this lower portion of the wall being separated from the upper cream-coloured portion by a line of black an inch broad, or better by a double line, the upper line being an inch broad, and the lower line three-eighths of an inch, the lines being separated from each other by five-eighths of the red or chocolate.

Fig. 47.

I like the formation of a dado, for it affords an opportunity of giving apparent stability to the wall by making its lower portion dark; and furniture is invariably much improved by being seen against a dark background. The occupants of a room always look better when viewed in conjunction with a dark background, and ladies' dresses certainly do.

The dark dado gives the desired background without rendering it necessary that the entire wall be dark. If the furniture be mahogany, it will be wonderfully improved by being placed against a chocolate wall.

The dado of a room need not be plain; indeed, it may be enriched to any extent. It may be plain with a bordering separating it from the wall, such as Figs. 43, 44, or 45; or it may have a simple flower regularly dispersed over it; or it may be covered with a geometrical repeating pattern, in either of which case it would have a border; or it may be enriched with a special designed piece of ornament, as Fig. 46. This particular pattern should not, however, be enlarged to a height of more than twenty to twenty-four inches; but if of this width, and above a skirting of twelve or fifteen inches, it would look well.

I have designed two or three narrow dado papers for Messrs. Wylie and Lockhead of Glasgow, which are about eighteen inches broad, and are printed in the direction of the length of the paper, so as to save unnecessary joins.

If the dado is enriched with ornament, and the cornice is coloured, and a pattern goes all over the ceiling, the walls can well be plain, but they may be covered with a simple "powdering" as the patterns in Fig. 47, if these are in soft colours.

A good room would be produced by pattern Fig. 48 being on the ceiling in dark blue and cream colour, by the cornice being coloured with a prevalence of dark blue, the walls being cream-colour down to the dado; the border separating the dado from the wall being black ornament on a dull orange colour, and by the dado being chocolate with a black rosette upon it; the skirting boards being bright black. The dado may or may not be varnished; the upper part of the wall can only be "dead" (not varnished, dull). If the room is high a bordering may run round the upper portion of the wall, about three to four inches below the cornice; such a border as Fig. 49, may be employed in dull orange and chocolate.

A citrine wall comes well with a deep blue, or blue and white ceiling, if blue prevails in the cornice, and this wall may have a dark blue (ultramarine and black) dado, or a rich maroon dado (brown lake). If the blue dado is employed the skirting should be indigo, which when varnished and seen in conjunction with the blue, will appear as black as jet.

Walls are usually papered in middle-class houses. I must not object to this universal custom; but I do say, try to avoid showing the joinings. In all cases where possible, cut the paper to the pattern, and not in straight lines, for straight joinings are very objectionable. If you use paper for walls, use it artistically, and not as so much paper. Let a dado be formed of one paper, the dado bordering (dado rail) of a suitable paper bordering; the upper part of the wall being covered by another paper of simple and just design, and of such colour as shall harmonise with the dado. Proceed as an artist, and not as a mere workman. Think out an ornamental scheme, and then try to realise the desired effect. Avoid all papers in which huge bunches of flowers and animals or the human figure are depicted. The best for all purposes are those of a simple geometrical pattern, or in which designs similar to those in Fig. 47 are "powdered" or placed at regular intervals over a plain ground.

* In some parts of the country it is customary to wash the cornice over with quick-lime. If this has been done, the lime must be carefully removed, for lime will turn carmine black.

Fig. 46.

Fig. 48.

Fig. 43.

Fig. 44.

Fig. 45.

Fig. 49.

COLOUR.—XI.

By Professor Church, Royal Agricultural College, Cirencester.

SURFACE AND STRUCTURE MODIFY COLOUR—COLOURS OF METALS—DAMASCENING AND PLATING—ENAMELLING ON GOLD AND SILVER—LACQUERING—COLOURS OF GEMS—COLOURED MARBLES.

The colour of objects is influenced not only by the nature of the light by which they are illuminated, but also by their own peculiarities of texture, structure, and surface. The coloured light reflected from satin is different from that of velvet, though the silk used in the manufacture of these fabrics may have been dyed in the same bath. In explaining modifications of colour produced by texture, etc., we shall select a series of illustrative examples from the mineral, vegetable, and animal kingdoms. We shall then proceed to explain their colour-peculiarities, and the manner in which these may be utilised, in decorative art more particularly.

Metallic colours first claim our attention. Polished metals are distinguished for their intense power of reflecting light, and for an almost complete opacity. An intense reflection of light is also observed with other than metallic surfaces, such, for instance, as the neck of the peacock, and that beautiful chemical salt, the magnesium platinocyanide. But there are some points in which these lustrous colours differ from those of the true metals. We have alluded to this subject in Lesson I., and may here proceed to apply the principles of absorption and reflection of colour there laid down to the special case of metallic colours. Now it will be allowed that, under ordinary circumstances, metals do not appear highly coloured, though their brilliancy is often intense. The angle of incidence of the light has much to do with this. When we take a polished and level plate of gold or copper, and look along its surface, we shall see it appear very brilliant, but nearly white. In such a case, the rays of light which illuminate it almost graze the surface, making an angle of nearly 180° with the reflected rays that reach the eye. But let this angle be reduced to one of a few degrees only, then the proper colour of the metal will be conspicuous. It may be still further developed and enriched by repeated reflections at a small angle of incidence. Fig. 19

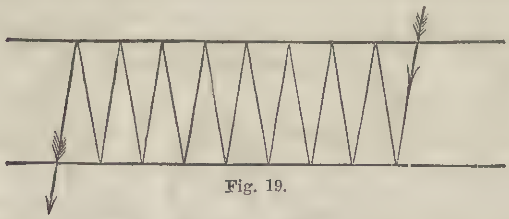


Fig. 19.

illustrates the mode in which a beam of light may become in this way more highly saturated with colour by numerous reflections from two polished surfaces of metal. From this cause chased gold and "granulated" gold appear of a far richer colour than burnished gold. And by so shaping the grooves or lines of chasing upon any piece of coloured metal, that repeated reflections at small angles of incidence occur in them, very rich colour-effects may be produced. The splendid colours inside gold or gilt goblets arise from this cause. Many metals which lack distinctive colour under common conditions may thus be made to develop it. Yet the colour thus produced not only changes in tone or saturation as it becomes enriched, but its quality is also modified. Thus copper may be made to yield ultimately a nearly pure or monochromatic red light by repeated reflections. The colour is more distinct, it is purer; but there is less light.

The colour of a pure metal may be greatly altered by alloying it, even slightly, with another. Thus, gold 22 parts, with 2 parts of silver, produces a metal of a greenish colour, which may be rendered still more decided by a small further addition of silver. Copper, on the other hand, to the extent of 10 or 12 per cent., reddens gold; while a small admixture of both copper and silver does not materially affect its colour, though it makes it rather paler. A large proportion of silver, varying from 20 to 50 per cent., produces *electrum*, some specimens of which, where the silver exists in nearly equal proportion with the gold, are almost white. Ancient and modern coins, as well as jewellery, furnish interesting examples of the variations in the colour of gold produced by alloy. The old Roman gold coins, with less than 1 per cent. of alloy, show the rich characteristic orange tint of the pure metal; while in a handful of modern sovereigns the yellowish-orange ones indicate the presence in the alloy of copper and silver; the greenish ones indicate silver alone, and the reddish ones copper alone. Slight as these differences of colour would appear did they belong to ordinary pigments, yet, in the case of the metals, the intensity of their reflection enables us to use with effect coloured varieties of gold in ornamental jewellery. Gold, if not alloyed very much (not more than 9 parts in 24), may be made to assume its proper colour by a process of "pickling" or "colouring." Gold articles plunged when warm into nitric acid lose a portion of their superficial alloy, be it copper or silver, the pure metal being left with a somewhat *matt*, or dead surface, and a rich orange colour. Or a mixture of equal parts of borax, nitre, and sal-ammoniac may be made, ground into fine powder, mixed with a little water, and applied as a thin coating to the metal. The metallic object is then heated till a faint discolouration appears on the coating; afterwards, the paste being washed off, the pure gold film will appear beneath. With a film thus prepared, and with some of those films which are obtained by electro-metallurgical processes, the brilliancy of the metallic reflection is much impaired, though its characteristic colour may remain. This alteration arises from the loss of continuity of the metallic surface. Silver, in fact, may be so precipitated from a solution as to present a surface almost indistinguishable from a sheet of cream-wove white paper; and gold may be obtained by similar processes in a state which presents a close resemblance to yellow ochre. Some of the most beautiful effects in the decorative employment of metals may be obtained by the partial polishing or burnishing with an agate or steel tool, of such matt or dead surfaces as these. When silver is deposited by Liebig's silvering liquid on glass, it may be made to assume a most perfect, or "black," lustre, and is then applicable for use in mirrors or in the reflectors of telescopes. Here the continuity of surface is practically perfect.

The delicate and subtle contrasts between metallic colours has led to the association of two or more metals in several kinds of decorative work. We have already referred to the varieties of coloured gold. In jewellery red gold may be used for flowers, with white gold or electrum; green gold may be employed for leaves; while the ornamental spray itself may be laid upon a chased or granulated surface of pure orange-coloured gold. By the process of parcel-gilding on silver, a more decided difference of colour may be secured; while the methods of metallic inlaying and damascening enable us to obtain the more marked contrasts between iron and gold and iron and silver. In these latter cases we have not only a considerable difference of colour between the two metals, but a very distinct difference in reflecting power. Iron or steel covered, by an easy chemical method, with a film of platinum, is preserved from corrosion, and still furnishes an excellent combination with silver or gold, or with both of these metals, as inlays.

Before giving a list of the colours of a few metals in their pure and unalloyed state, we may remark that other metals besides gold are remarkably modified in hue by the presence of alloy. Perhaps copper shows this effect more commonly and more distinctly than any other. An alloy of 85 parts of copper with 15 parts of tin, or with 15 parts of a mixture of tin and zinc, constitutes a mixed metal of a rich yellow colour, the pink colour of the copper being then much altered. So 5 parts of the bluish-white metal aluminium will similarly modify the colour of 95 parts of copper, an effect seen in the so-called aluminium gold, or aluminium bronze, which is thus constituted. If the copper be mixed with tin in the proportion of 70 of the former metal to 30 of the latter, then the alloy is no longer yellow, but greyish-white, forming what is known as *speculum metal.*

The colours of some of the metals, in a few cases ascertained and determined by two or more reflections, are here given :—

Copper	*red.*	Silver	*orange-yellow.*
Gold	*orange.*	Sodium	*rosy pink.*
Lead	*bluish-grey.*	Steel	*neutral grey.*
Mercury	*slaty-grey.*	Tin	*greyish-yellow.*
Potassium	*lavender-grey.*	Zinc	*bluish-white.*

There is one remarkable and important property enjoyed by metals, and particularly by gold, of at once harmonising with and setting off ordinary coloured materials. Two instances of such a use of gold will occur to every one—the gilt frame of a picture, and the gold threads in embroidery. Gold, in fact, is removed from the series of ordinary paints and dyes by the intensity of its metallic lustre, and so combines into agreeable assortments with all colours, even with those with which yellow and orange pigments do not associate well. In a picture-frame this peculiarity of its metallic lustre prevents its yellow colour from interfering with the similar hues of the picture, while its colour being luminous and "near," gives the idea of some degree of distance to the picture itself. We seem to look through an opening into the scene represented.

Gold, and other metals as well, may have their lustre made use of as a brilliant background for the development of colour. A transparent film of some sort is often placed upon metals, and when this film is coloured, such part of the light as escapes reflection at its surface passes through it, is reflected from the metal behind, and again passes outwards, leaving the film strongly tinctured with its colour. Films of this kind are of two sorts, one kind belonging to the vitreous or glassy series of materials, and the other being resinous, that is, essentially similar to a varnish. These transparent films are applied to metals for three purposes—to protect the surface, to cause an inferior metal to assume the aspect of a more precious one, and to produce certain colour-effects not otherwise attainable. Silver, when varnished with white lac, loses some of its brilliancy, but is no longer liable to tarnish. Iron and brass may be protected from corrosion, and improved in appearance, by a lacquer in which the red resin known as *dragons' blood* is an ingredient. With this preparation, silver assumes something of the rich aspect of gold, and iron resembles bronze. Resinous substances may be applied to metals either in the form of varnishes—that is, of solutions which dry and leave a continuous film or coating of the resins they contain—or by means of fusion. In the latter case the finely-powdered resin may be introduced in a pasty form mixed with a little water into the grooves, etc., prepared to receive it, and then heated to the temperature necessary to produce fusion. True translucid enamels of the vitreous class, on the other hand, require a much higher temperature than the resin, and yield far superior and more varied results. They consist essentially of different kinds of glass, coloured suitably with metallic oxides. Blue enamels thus contain cobalt; puce and violet enamels are furnished by manganese; grass green by chromium sesquioxide, and so forth. Such enamels appear on silver of their proper colour, but on gold the hue of the metallic background produces a change of colour, sometimes advantageous, sometimes the contrary. But as the colour of gold may be greatly modified by a little, it is easy to select or prepare a quality of gold suitable for the several coloured enamels in use. The following list gives the most appropriate metals for a few colours:—

Green.—Gold of 20 carats with 4 carats silver alloy.

Red.—Gold of 22 with 2 carats copper, or a mixed alloy.

Violet, rose, white, yellow.—Silver, or, less suitably, white electrum.

Puce.—Electrum of 16 carats gold, 6 carats silver, or gold 20 carats fine.

Brown.—Gold of 20 to 22 carats.

The subject of translucid enamels naturally leads us to the consideration of gems and glass. It ought scarcely to be necessary to vindicate for the natural precious stones a very high position amongst decorative coloured materials. Besides the hardness of the more esteemed sorts of jewels, they present beauties and singularities of colour and optical effect which are, to a great extent, quite inimitable by artificial methods. Yet amongst a certain clique of artists and amateurs it has become the fashion to depreciate their excellence, and, further, to insist upon their being cut, if used at all, in a way which is usually fatal to the development of those qualities upon which the beauty of precious stones depends. This method is known as the cutting *en cabochon* or "tallow-topped," and is applicable or appropriate, as a rule, only to those stones which are not perfectly transparent—opals, cats'-eyes, chrysoprases, etc. When applied to transparent gems, it prevents the full play of light and colour proper to them, internal reflection is imperfect, and the marvellous dispersive power often present does not show its effect in producing the so-called *fire* of the stone. Analysed with a prism, the colour of gems is often found to differ from that of the nearest approach in artificial "paste"—that is, glass—that can be manufactured to represent them. Then, too, gems often exhibit peculiar optical properties which no fused artificial substances can possess. The minute internal fissures, to which the splendid play of colours in the precious opal of Hungary and Mexico is due, cannot be imitated, though there is another mineral, *sphene*, which possesses this remarkable quality in a high degree. The opal is seen best upon a black or dark-blue background of enamel, and is still further enhanced in beauty by a border of small diamonds, which form a delicate yet effective contrast, through their perfect transparency and purity, and their almost metallic lustre, with the milkiness and variegation of the opal. The stones known as star-stones have also optical peculiarities, which are quite inimitable. These gems are essentially crystallised alumina, and are known as star or asterias rubies or sapphires, according to their colour; they are translucent only, and owe their beauty to a peculiarity of their minute crystalline structure. This is revealed when one of these crystals is cut across its principal axis, and left with its top *en cabochon*. Then a six-rayed star makes its appearance, best seen in sunlight, or by the light of a small brilliant flame, or in the focus of a condensing lens. It is due to the symmetrically disposed *layers* of which the crystal is built up. The less transparent varieties of red garnet, when cut as carbuncles, occasionally show a star, but it has only four rays, owing to the simpler crystalline structure of the stone in this case. Among other *chatoyant* stones with a play of light upon or in them, the moonstone, a species of nearly colourless and transparent felspar, is one of the most familiar. Its light is more diffused than that of the star-stones, and has a pearly whiteness. Moonstones may be very effectively combined with dark-coloured clear amethysts, the contrast being not only of colour but of lustre. The stones called cats'-eyes are of two species: one of them, the more precious, is yellow or yellowish-green, hard, and shows a pale bluish line of light when properly cut; this is due wholly to the optical structure of the crystal itself. But in the commoner variety we merely have quartz penetrated with fine fibres of asbestos, which catch and reflect the light. There is one peculiarity of precious stones which we cannot pass over, a property known as *dichroism*. A crystal which is greenish in one direction may appear rose-pink when seen in another. A ray of light is affected differently according to the direction in which it passes through the crystal. The tourmaline is an excellent example of this, a grass-green specimen of this stone appearing dark brown or even black when viewed along the principal axis of the crystal instead of across it. This, again, is a quality of some natural gems which cannot be imitated exactly in artificial mixtures.

We may here find occasion to introduce a word or two concerning the commoner sorts of ornamental and coloured minerals, ranging from agates down to tinted building stones. There are two points of special importance connected with such materials. One of these points is the undesirability of mixing natural with artificial materials in walls and pavements. It is very difficult to combine satisfactorily tiles and marbles. There is a faint approach to translucency in many marbles, which the dull, dry, opaque surface of unglazed tiles contrasts unpleasantly with, and glazed tiles are coarsely artificial in their gloss. Then, again, we have, in the second place, to remind our readers that marbles with natural veinings and mottlings of colour do not allow of sculptured ornament. Your surface decoration in relief will interfere with Nature's prior decoration in colour. The wildness and almost infinite variations of the natural tones of brown in a piece of Derbyshire alabaster are broken up when its surface is diapered with a conventional carved ornament—the natural picturesqueness and the artificial are incongruous. A surface in a tessera of mottled or veined marble, or a pillar, displays its beauties, but in a sculptured capital of the same material they are disfigured, while the light and shade of the ornamental design do not come out properly in the variegated material.

There still remain for study among mineral products glass, porcelain, and pottery. Opalescence and iridescence, as well as several other peculiarities influencing their colour-effect, are common in a measure to some kinds of all these artificial products, and we may, therefore, group them together for consideration in the next lesson.

TECHNICAL DRAWING.—XXXIV.

DRAWING FOR MACHINISTS.

WHITWORTH'S 15-INCH SLIDE-LATHE.

FIG. 344 (*a*, *b*) represents the headstock, slide-rest, and part of lathe-bed in elevation.

On the countershaft (Fig. 345) there are two sets of pulleys, A, B, B and A′, B′, B′, each driven by separate straps from the main shaft. The sets A and A′ run in opposite directions, the former for driving the lathe, and the latter for reversing it; and for this purpose it is driven by a crossed strap. The

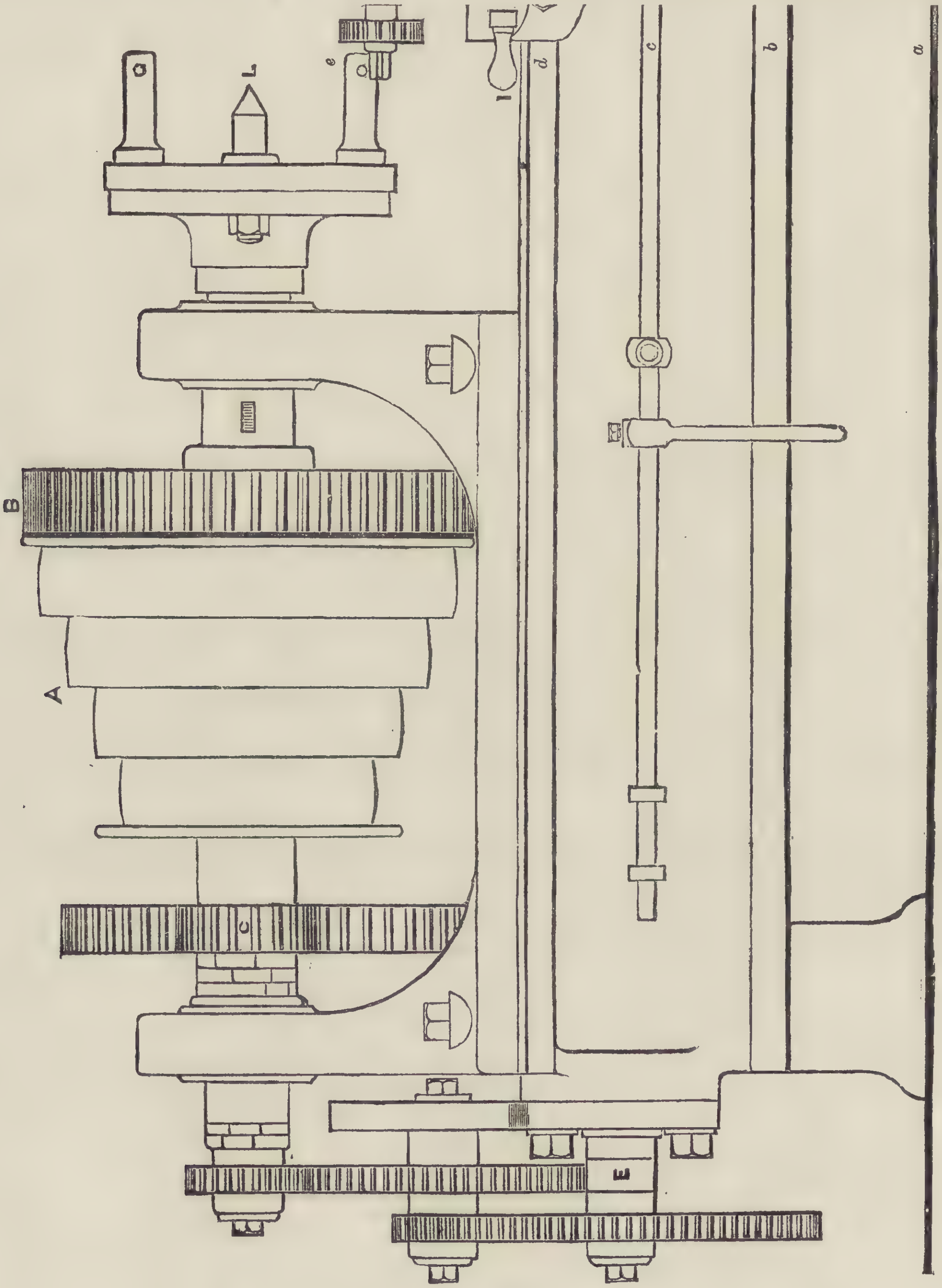


Fig. 344 (*a*).

*** Owing to the great length of Fig. 344, it has been necessary to show it in two parts. The junction of the portions of the figure, as shown in the two parts marked Fig. 344 (*a*), 344 (*b*), is sufficiently indicated by the letters *a*, *b*, *c*, *d*, *e* in each, and the connection of the two parts of the machine thus unavoidably separated is shown by the repetition of the spur-wheel in each portion.

The use of a lathe is to turn iron or other materials into a circular shape, and it does this by causing the object held between its centres L (Fig. 344 [*a*]) and L (Fig. 347), to rotate against a cutter, F, held in the rest, G (Fig. 344 [*b*]). While the object is in motion the cutter is made to slide along the lathe-bed, and so come against new uncut portions of the object at every revolution, and thus, by continually removing the outer irregular surface, a cylindrical form is given to it.

pulleys B, B, B′, B′ are all loose upon the shaft, and the strap-forks, D and D′, can be moved by a vertical rod (not shown), or by the horizontal bar in front of lathe-bed, as shown by Figs. 344 and 347, which will be given in the next lesson.

Both straps are on loose pulleys, as the forks are arranged in the drawing. But if they be moved to the right, then one will be on the fast pulley, A, and the other on a loose pulley, B′; consequently, the lathe will run in its proper forward direction,

By moving the forks to the left hand, the crossed strap drives the pulley A′, and thus reverses the lathe. This arrangement of pulleys is necessary for cutting screws, so as to run the tool back without changing the position of the threads of the guide-screw relatively to those of the screw which is being cut by the lathe.

By putting the strap on any cone of the pulley C leading to the lathe, variations in speed may be readily obtained.

In order to make the machinery self-preserving from accident, a stop is fixed on the bar in front of the lathe which moves the strap-forks, so that a stud upon the slide-rest shall move the strap upon a loose pulley, and stop the lathe before any damage can take place from contact between the slide-rest and fixed headstock by the guide-screw overwinding.

Fig. 346.

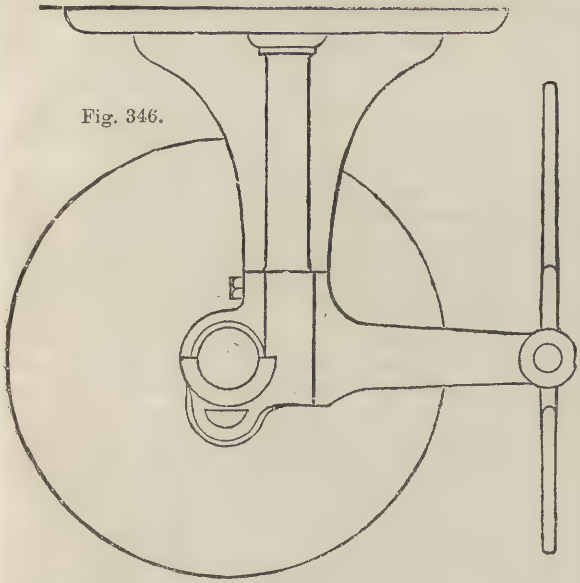


Fig. 344(b).

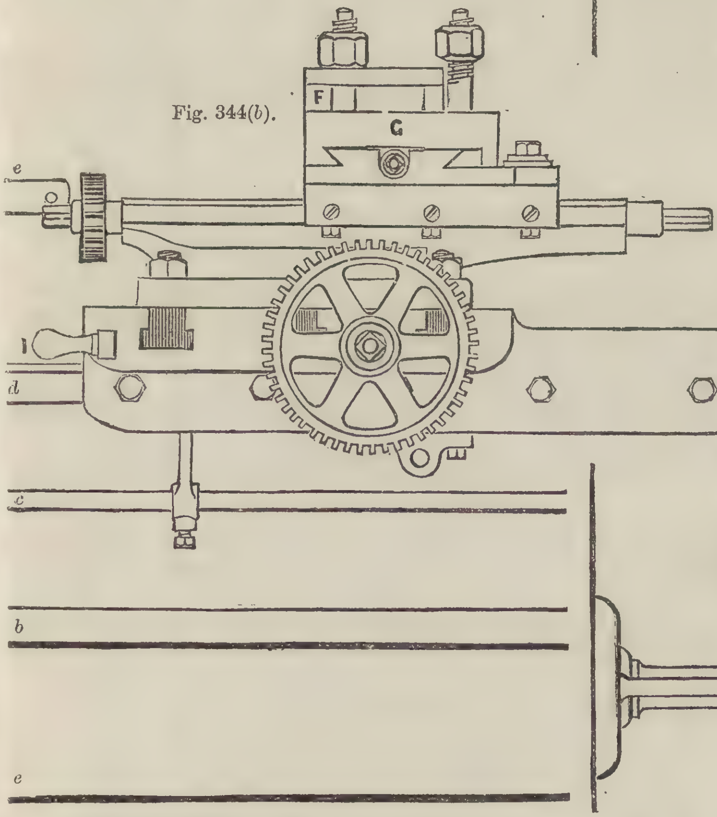
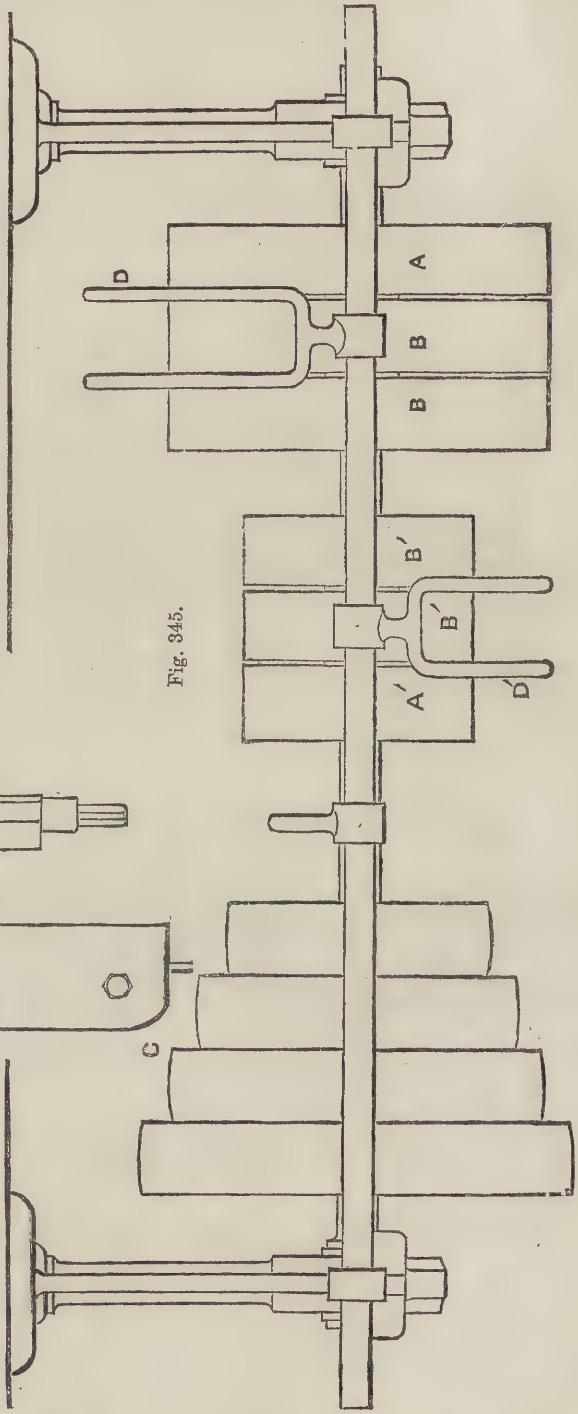


Fig. 345.



Figs. 345 and 346.—The countershaft which drives the lathe and receives motion from the main shafting.

Motion having been given to the cone-pulley A (Fig. 344 [a]), which runs loose on its shaft, is communicated to the large spur-wheel, B, by a key placed between them, and so the lathe-shaft is driven; or to produce a slower rate the key is re-

moved, and the second motion, or back-gearing, brought into use, and driven by a pinion, C, attached to the hinder end of the cone-pulley. Another pinion on the second shaft, D (Fig. 348, which will also be given in the next lesson), drives the large wheel, B, so a double reduction of speed takes place. By the variation of speed due to the cones and back-gearing, eight different rates may be given to the lathe, and a suitable velocity imparted to any object held between its centres.

At the back end of the lathe are a set of change-wheels that give motion to the screw E, which runs along its whole length inside, and is protected by the bed. As their name implies, these wheels can be altered so as to give any desired speed to the travel of the tool F (Fig. 344 [*b*]), held in a slide-rest, G, and moved by the screw. By suitable proportions, threads of any pitch can be cut by the tool; and each lathe of the kind illustrated is provided with a complete set of toothed wheels, used either for sliding the rest slowly along, for turning shafting, etc., or cutting screws of any usual pitch.

The compound slide-rest, G, affords a means of placing the tool in any relative position to the work in hand: it consists of two V-slides at right angles to each other, which may be worked either by hand or self-acting arrangements, and a holder to carry the cutting tool. It is shown in front elevation at G (Fig. 344 [*b*]), and in side elevation at H (Fig. 348). The handle, I (Fig. 344 [*b*]), at the left-hand side, is for lowering or closing a nut upon the guide-screw, E (Fig. 344 [*a*]), so as to put it in or out of action, without reference to the change-wheels being in gear or not, and so give motion to the slide-rest.

A portion only of the bed is shown—its total length would be fifteen feet. The opposite end will be given in Fig. 347, which also illustrates the movable headstock. This contrivance is nothing more than a centre to carry one end of an object in a lathe, and capable of being fixed in any part of the bed by means of the two nuts shown. The wheel K (Fig. 347) works an internal screw that advances or draws back the centre point, L. A locking-bolt, M, of which the end only is seen, holds the centre whenever required.

The illustrations show a good example of a powerful slide and screw-cutting lathe; it is strong and well-proportioned in all its parts, yet not heavier than is required to resist the strain of working and the vibration to which it is subjected.

SANITARY ENGINEERING.—II.

GAS-BURNERS, AND ECONOMY IN GAS CONSUMPTION.

In our first paper we gave a general account of the manufacture of gas by public companies, the material employed, the processes to which it was subjected, and the method of its distribution. The gas being thus as it were brought to our door, or, to use the strictly technical phrase, "laid on," we now proceed to consider the various mechanical appliances used in its consumption: of these the simplest is the jet. A nipple of cast-iron or some incombustible material—porcelain has been used with advantage—is screwed on to the end of the pipe, the aperture through which the gas issues and is consumed being a small single perforation, which we may call a pinhole.

We next have what is in technical phrase called the "batswing" burner. In this, instead of the pinhole, the end of the nipple is first cast solid, and then split, as we may say, by a fine saw, the broad spread flame that issues from the opening thus made giving its name to the burner from its fancied resemblance to a bat's wing; these are, each of them, though the simplest forms in use, extravagant in their consumption, as the direct escape given to the gas allows a certain portion to pass through imperfectly consumed. They are still used extensively in passages, workshops, and other inferior positions; the idea in the mind of the public apparently being, that any cheap burner will do for those situations, while the actual fact is that the extra quantity of gas burnt in proportion to the price given for the burner, entails a current expense which would repay the cost of a better burner many times over in the course of a week. These burners also rapidly corrode the passage for the gas, which becomes gradually widened, and a still greater waste is the result.

The burner in most general use for ordinary purposes is the "fish-tail," as it is called, which may be taken as the best "burner" pure and simple, when no adventitious aid of chimneys or artificial draught is available. In this burner the gas comes up through two pinholes, inclined towards each other at an angle of about 60 degrees; the effect of the pressure being that the flame assumes a fish-tail, or, as it is called in some provincial districts, a tulip form, and is thrown out on either side at right angles to the converging delivery of the jets.

These are the leading forms of simple burners. With their combination in groups as cockspur, flower, and other lights, and more especially as to the employment of a group of fish-tails in the form of the sun-burner, we shall deal at length in a subsequent paper, and now proceed to take up the more complicated forms known generally under the name of "argand."

The term "Argand" is the name of the inventor, who in the year 1780 discovered in the use of an oil lamp that a circular wick open in the centre from below, and surrounded by a glass chimney, gave an immense additional per-centage of light over the ordinary methods then in use; and this principle is applied to the consumption of gas by the adoption of a hollow metal ring perforated on its upper surface with a number of minute holes through which the gas passes, the flames uniting into one annular light. The "bude light" is a concentric series of similar rings; and there are an immense variety of different descriptions of this kind of burner, many of them the subject of patents for various improvements of detail: *e.g.*, in some instances the burner is formed of a number of small tubes forming a ring, and with their points of issue slightly converging, while a bend in the glass chimney occurs immediately above, so as to direct the draught of air more immediately upon the flame; but the principle is always the same, the two important points which control the supply being the size of the openings in the burner, and the length of the chimney: this last is a point which requires much attention, as if the chimney be too low the draught is insufficient and the consumption too slow; while if it be too high the contrary effect takes place, and in either case loss of light is the result.

These are the ordinary descriptions of burner in general use; and we now proceed to consider the principles involved in the *economical* consumption of gas. It is well understood that the larger in bulk the amount of any substance in combustion the greater amount of heat and light are obtained, and this proportion may be termed geometrical and not arithmetical: for instance, a ton of coals burning in one body in a grate or furnace will generate a far greater body of heat (and light is regulated by the same law) than the same quantity divided, say, into portions of one cwt. each, and burned in twenty separate stoves.

We may give as a practical instance of this, as applied to the generation of light, our ordinary lighthouses. The old-fashioned catoptric light, as it was called, consisted of a group of argand burners, each with its separate reflector; when the dioptric system was introduced—where one large central burner only is employed—it was found that a large annual saving in oil was effected, the light given being equal in amount. The same principle applies to all gas-burners, with the addition of another element, and that is the variation of the pressure of gas, which exercises a most important influence, both on the light and the consumption of the gas. We state this as the result of actual experiment often repeated. Two fish-tail burners may be selected, one technically called a Number 3, a small size, and another a Number 6, a large size, the smaller size being supplied with gas at a high pressure, and the larger one with gas at a low pressure, the matter being so regulated, that in a given time, say an hour, each burner shall consume the same quantity of gas. The result has often been shown to be that the Number 6, the larger burner, at the lower pressure, gives *double* the light of the other, each burning the same quantity of gas; and the rule, therefore, is that the lower the pressure at which the gas can be burned the more light will be obtained in return for the quantity consumed. The most profitable point of a burner's consumption—profitable in the sense of economy—is that at which it is just at the point of (but not actually) smoking. The lower, therefore, the pressure at which the gas can be delivered to the burner, the more economically will it be burnt. And we derive also from this another general principle, of much importance in lighting all areas of any size, such as theatres, chapels, churches, warehouses, etc., and that is, that one large burner will give double, at least, the light of a number of small ones, even supposing the same quantity of gas is consumed in each case. The danger of having too large an area for the emission of gas

from the burner is, that in case of an increase of pressure a certain waste ensues. This has been the subject of much attention to gas engineers, and has led, many years ago, to the invention of gas regulators, which, like the burners, have been the subject of various patents. The general principle upon which they are all constructed is to make the pressure of the gas itself the motive power which shall, by a self-acting process, control its own supply. This object is attained by an instrument constructed something on the principle of a miniature gasometer, through which the gas must pass when it leaves the meter and enters the service-pipes, the inverted tumbler or little bell of the regulator being provided with a valve which controls the exit of the gas by opening and closing. A high pressure lifts the bell, diminishes the opening of the valve, and reduces the supply of gas; a low pressure allows the bell to fall, thereby opening the valve and increasing it. They were made, when first invented, to be used with water; but as they have to be fixed within the house, and the water becomes rapidly impregnated with gas, an offensive smell was the result. This objection to their use, however, has been obviated of late years by the substitution of mercury (quicksilver) for the water, which keeps the regulator air-tight, and yet allows its freedom of movement. Where the pressure of gas is below the average, as in some low-lying districts, the regulator is not applicable; but in most cases, and certainly in all the higher parts of London, the force required to carry the gas through the long series of pipes is so great that their adoption effects a great saving. They are inexpensive machines, and have often been known to pay the cost of their introduction in the saving of gas effected in the course of a few months. Most of our readers have, no doubt, noticed the flaring that often comes on late at night, when the gas is being gradually turned off in the shops, which necessitates the "turning down" of the gas several times perhaps in the course of the evening; this is entirely controlled by the regulator, which secures a regular supply to the burners, and neutralises the extra pressure thus occasioned.

Further, we may remark that in many thousands of houses, by a careful re-consideration of the sizes and proportions of the burners required in the various rooms, and the introduction of a regulator, a saving of 30 per cent. of gas may be easily effected.

Our limits are nearly reached; but we will conclude with a few words on the removal of products of combustion where gas is largely employed—a point to which, from sanitary reasons, too much attention cannot be paid. This is sometimes effected, in the case of single burners, by a bell-glass, from the top of which passes a pipe into the nearest flue—a very desirable method where practicable. The late Professor Faraday invented a light in which an argand burner was entirely encased, chimney and all, in a large glass globe, from which was a pipe acting as a sort of flue; the effect being that the products of combustion were removed, either to a flue or the external air, without mingling in the slightest degree with the atmosphere of the room. And there are many similar adaptations of this principle, which has been introduced, among other places, at Marlborough House. Much the same effect is attained by the modern introduction of the "sun-burner," which also acts as an independent ventilator, removing the vitiated air from the upper portion of the room. It is, however, only applicable to comparatively large areas, and will probably form the subject of one of our subsequent papers; while the removal of gas products will be dealt with at length under the head of ventilation generally.

NOTABLE INVENTIONS AND INVENTORS.

XIII.—WILLIAM LEE AND THE STOCKING-FRAME.

BY JOHN TIMBS.

The earliest stockings worn in England, by Henry VIII., were "cloth hose" or yard-wide taffeta, except there came from Spain, by great chance, a pair of silk stockings. Such is Howell's statement; but that woollen stockings were not only in use, but perhaps knit in this country, during the reign of Henry VIII., seems placed beyond doubt by this authentic household record: "1533, 25 H. 8. 7 Sept.—Peyd for 4 peyr of Knytt-hose, viii s." As early as the third year of Elizabeth we read that the queen's silkwoman presented to her majesty a pair of black silk knit stockings made in England, which pleased her so much, that she would never wear any cloth hose afterwards; not only on account of the delicacy of the article itself, but from a laudable desire to encourage this new English manufacture by her own example, and henceforth she wore no more cloth stockings. Soon after this (says Stow) William Rider, an apprentice at London Bridge foot, opposite the church of St. Magnus, seeing a pair of knit worsted stockings at an Italian merchant's, brought from Mantua, borrowed them, and having made a pair like them, presented them to the Earl of Pembroke, which was the first pair of worsted stockings knit in this country.

The manufacture of stockings by the humble process of knitting is, in strictness, to be called "chain weaving;" for the fabric itself is actually produced by a series of links or loops in a thread of worsted, cotton, or silk. In the process of knitting, still carried on to a small extent in secluded country districts, polished steel needles or wires are used to link the threads together into a series of loops, closely resembling in their character the loops produced by tambouring. But this method was almost entirely superseded by the ingenious stocking-frame, which, next to the common warp and weft loom, is the oldest machine in existence applicable to textile fabrics. It dates from almost immediately after the introduction of knit stockings, or from 1589, the thirty-first year of Elizabeth's reign.

In the early history of the stocking-frame there is a strange confusion of persons, places, and dates, in the accounts given of the invention and the inventor, which neither Beckmann nor any other inquirers have entirely succeeded in removing, unless we implicitly believe the evidence of a painting which long hung in Stocking Weavers' Hall, Redcross Street, Cripplegate, long since taken down. This picture contained the portrait of a man in collegiate costume, in the act of pointing to an iron stocking-frame, and addressing a woman who was knitting with needles by hand. The painting bore the following inscription: "In the year 1589, the ingenious William Lee, A.M., of St. John's College, Cambridge, devised this profitable art for stockings (but being despised, went to France), yet of iron to himself, but to us and to others of gold: in memory of whom this is here painted." From Deering's "Account of Nottingham," it appears that William Lee (whose name is sometimes written Lea) was born at Woodborough, a village about seven miles from Nottingham: he is said to have been heir to a good estate, and he was a graduate of St. John's College, Cambridge. Tradition assigns the origin of Lee's invention to a pique he had taken against a townswoman with whom he was in love, and who, it seems, slighted his passion. She got her livelihood by knitting stockings, and with the ungenerous object of depreciating her employment he constructed this frame, first working at it himself, then teaching his brother and other relations. Another account states that the girl, during his visits, paid more attention to her work than to her lover, and he endeavoured to find out a machine which might facilitate and forward the operation of knitting, and by this means afford more leisure to the object of his affections to converse with him. Beckmann, however, argues that a machine so complex in its parts as the stocking-frame, and so wonderful in its effects, would seem to require longer and greater reflection, more judgment, and more time and patience than could be expected in a lover.

Another version of the story states that Lee was expelled the University for marrying contrary to the statutes. Having no fortune, the wife was obliged to contribute to their joint support by knitting, and Lee, while watching the motion of his wife's fingers, conceived how to imitate those movements by a machine. Both accounts agree that the stocking-frame was invented by Lee. A writer in the *Quarterly Review*, however, observes: "This painting might give rise to the story of Lee's having invented the machine to facilitate the labour of knitting, in consequence of falling in love with a young country girl, who, during his visits, was more attentive to her knitting than his proposals; or the story may, perhaps, have suggested the picture."

There is, however, another claimant. Aaron Hill ascribes the invention to a young Oxonian, who having married imprudently, and having nothing to support his wife but the produce of her knitting, invented the stocking-frame, and thereby accu-

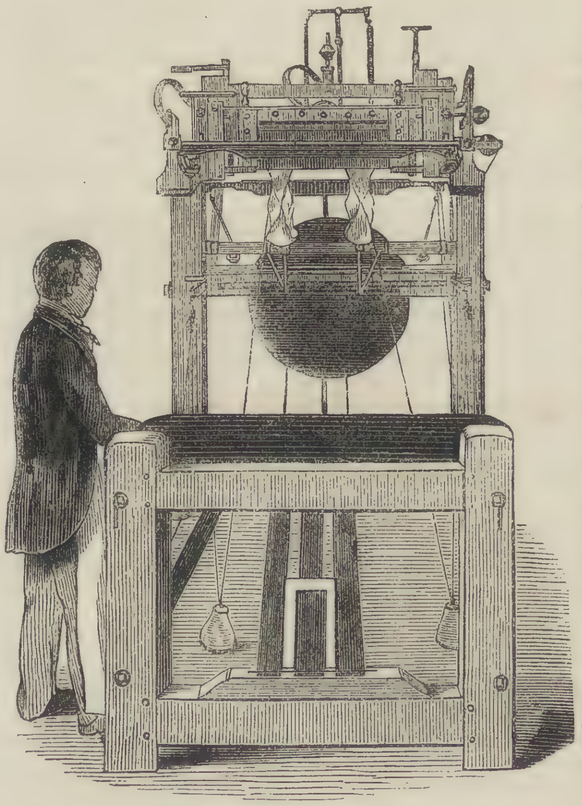
mulated a large fortune; but Hill wrote this story in 1715, upon hearsay. Evelyn, in his "Diary," records having seen this machine as follows: "3 May, 1661.—I went to see the wonderful machine for weaving silk stockings, said to have been the invention of an Oxford scholar about forty years since;" thus placing the invention many years later than the date of the picture in Stocking-Weavers' Hall. Evelyn's version is not a whit more exact than Hill's, which Elmore has followed in his very clever picture, painted in 1847.

Lee practised his new invention some time at Calverston, a village about five miles from Nottingham, and he, or his brother, is said to have worked for Queen Elizabeth. Another account states that Lee, finding himself neglected both by the queen and her successor, James I., and much annoyed by other stocking manufacturers bringing his invention into disrepute, transferred himself and his machines to France, where Henri IV., and his sagacious minister Sully, gave the inventor a welcome reception. Lee is said to have carried over nine journeymen and several looms to Rouen, in Normandy. Nevertheless, after the assassination of Henri, Lee shared in the persecutions suffered by the Protestants, and is said to have died in great distress, of grief and disappointment, in Paris. Seven of Lee's workmen escaped to England, and with Lee's apprentice, one Aston, established the stocking manufacture permanently in England. Aston, who had been a miller, added something to his master's invention. Stow says that Lee not only manufactured stockings in his frame, but "waistcoats and divers other things."

In the year 1663, Charles II. granted to the Framework Knitters' (stocking-makers') Society of London a charter, which Cromwell had refused to them a few years before. In their petition, the machine is described as consisting of 2,000 parts, and making almost instantaneously 200 meshes. Six years afterwards, the number of stocking-frames in England amounted to 700, employing 1,200 workmen, of whom three-fifths made silk stockings, and the others worsted; for cotton was not then ranked among English manufactures. By the year 1714 the number of frames had increased to 8,000 or 9,000. Our makers soon exported vast quantities of silk stockings to Italy, where they were known as "right English." By the year 1753, about twenty years after the introduction of cotton stockings, the number of frames in England was 14,000. Mr. Jedediah Strutt, of Belper, invented in the year 1758 a machine for making ribbed stockings, which he patented; the patent was twice contested, first by the houses of Derby, and then by those of Nottingham; but the validity of the patent being established, the inventor enjoyed it for fourteen years. The rib stocking-frame was one of the contrivances which led by gradual improvements to the net machines.

Here it may be interesting to trace the picture of Lee and his wife, which appears to have been parted with by the Framework Knitters' Company at a period of pecuniary embarrassment. Mr. Bennet Woodcroft has collected some particulars of the disposal of the picture, in the hope that they may lead to its recovery. In a list, dated 1687, of plate, paintings, etc., belonging to the Company, is this item, "Mr. Lee's picture by Balderston." It is described also in Hatton's "London," 1708. From 1732, the Company's books show no more meetings at the hall, or any further entry of the picture. The stocking-weavers subsequently let their hall, and met at various taverns. The head of the court summons, dated 1777, is engraved from Lee's picture, and from this plate is copied an engraving in the Gallery of the Portraits of Inventors in the Great Seal Patent Office. The picture is thought to have passed, about 1773, into the hands of an influential member of the Court of Framework Knitters, who from time to time lent the Company money, as their books testify. ("Curiosities of London," 2nd edit.)

The common stocking-frame is a quadrangular arrangement of upright posts, connected by cross pieces at the top, and having on one side the weaver's seat. Near this is placed a series of curved needles, which serve as knitting needles in forming the loops, in number according to the coarseness or fineness of the stocking. The stocking-frame has a series of vibrating levers, called jacks, which, aided by other intricate apparatus, throw the stocking-yarn into such curvatures as enable the needles to form the loops. The weaver has a bobbin-yarn at one side of his frame, from which he unwinds enough to lay across all the wires. He then, by moving certain treadles with his feet and levers with his hands, forms this length of yarn into a row of loops; and at the next movement, when forming another row of bends or loops, he links the one row into the other, so as to form a kind of chain, which chain, extending both lengthwise and across, constitutes the web of the stocking. One continuous thread forms both warp and weft; and as the thread is not by this operation tied into knots, such as occur in making nets, the meshes are loose; but at the same time the web acquires a degree of elasticity which no other form of woven plexus presents.



THE STOCKING-FRAME.

There are three classes of operatives engaged in the manufacture: the *winders*, who put the silk, cotton, or thread on the bobbins; the *stockingers*, or *framework-knitters*, who work the thread into a knitted fabric; and the *seamers*, who make the stockings out of the pieces thus produced. Some of the frames are owned by the workmen, and some are lent out or rented.

Stocking-frames with a rotatory motion, and worked by steam-power, have superseded the old unpromising engine, and effected very great economy. The working of a rotatory machine, impelled by steam, in which the new-fashioned stockings are made at the same time, will require the superintendence of only one man and a boy; whereas, in the old frame, but one stocking could be made at once by a single workman.

Loughborough is a chief seat of some manufactures of the best hosiery. The stockings known as Angola and Merino are made on the principle of combining worsted with cotton in nearly equal proportions; and the peculiar features of the best make are the close and intimate intermixture of the fibres of the wool and cotton. The separate materials are first passed through a machine called a picker and blower, the object of which is to clean and lighten it, so that half an ounce would fill a bushel measure. They are then carded together by carding machines, part of each material being dyed blue or black, and the intermixture is effected by the carding. It is next spun of various fineness by throstles and mules, and then given out to be woven.

FORTIFICATION.—VI.

BY AN OFFICER OF THE ROYAL ENGINEERS.

FLANK DEFENCE FOR REDOUBTS.

THE obstacle offered by the ditch of a work, with the dimensions usually attainable in the field, is so inconsiderable that it is of the greatest importance to provide some flanking defences for it, to increase the danger and difficulty of an assault.

The arrangements for attaining this end, by means of fire from the parapets, enable the defenders to take the storming parties in flank while crossing the glacis, as well as when actually in the ditch itself; but, on the other hand, it seems doubtful whether this advantage is not more than counterbalanced by the attendant defects of increased length of parapet and liability to enfilade, which would probably cause the flank defence to be crippled at the very instant it was most required, viz., the last moments of the attack.

To these reasons, and also to the fact that the simple trace of a redoubt is more capable of adaptation to irregular ground than that of a fort, is probably owing the circumstance that in almost every instance when closed field-works have been employed of late years the former trace has been adopted—*e.g.*, the Danish redoubts at Düppel, 1864; the double line of redoubts round Vienna, 1866; and the works thrown up round Dresden by the Prussians in the same year. In all these cases the works were traced rather with reference to the directions in which offensive fire was required, and to the reciprocal flanking fire of the collateral works, than to any idea of their own flank defence; and in many cases the ditches were altogether undefended.

That such flank defences, however, are still thought advisable by foreign as well as English engineers may be seen from the fact that in the works of this class at the Russian intrenched camp in Finland the ditches are defended by kaponiers, and that they have been provided for in the approved type of hasty redoubt in the latest work on military engineering at Chatham.

Flank defence for the ditches of redoubts is obtained by building covered loopholed galleries in them in such positions that, while being well screened from the enemy's distant fire, they thoroughly command one if not two ditches (Figs. 41, 42). These are called kaponiers and reverse or counterscarp galleries, according to their position. Their actual construction is simple enough, and yet from the fact that they are necessarily at the bottom of the ditch, and that their roofs are covered with earth, it follows that they cannot be begun until the ditches are nearly finished, and that some of the earth will have to be moved twice; consequently, when the works are hastily thrown up it will often be impossible to get these buildings constructed, however desirable and even necessary it may be to do so.

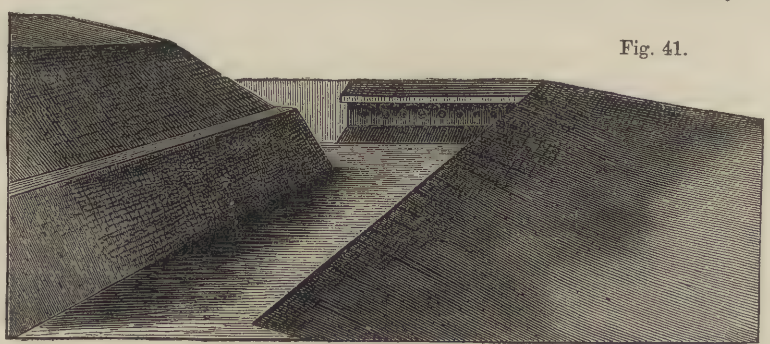


Fig. 41.

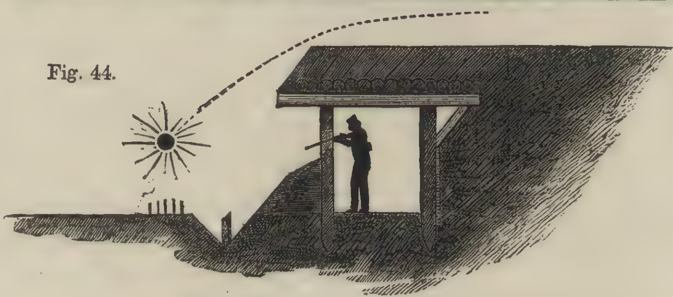


Fig. 44.

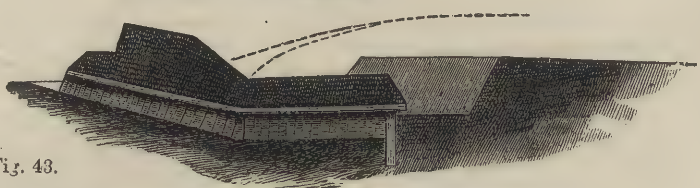


Fig. 43.

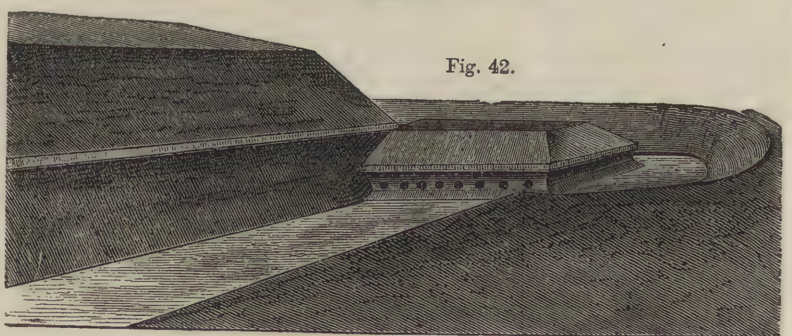


Fig. 42.

In some cases, when the skilled labour of sappers is available, time may be saved by laying the roofing beams on the ground in the ditch at the required level, and then employing a double set of workmen, one excavating the earth under the beams to form the interior of the gallery, while the other excavates the ditch, and forms the roof with the earth thrown out.

In this case of course the sides of the gallery are of earth, but as a rule the side and front walls are constructed of stoccade work, roofed in with thick beams of wood, covered by a sufficient thickness of earth, usually from three to five feet (Figs. 42 and 44).

A kaponier is a loopholed building projecting from the escarp across the ditch; and, in order to obtain as much fire as possible from it, the length of its sides should be the full width of the ditch; but as the roof would then afford a ready means of entering the work, the ditches at these points are carried round the end of the kaponier to prevent this. There is usually a covered passage leading from the interior of the work to the kaponier, to enable its garrison to be reinforced, and which enables them to retire to assist the defence elsewhere when no longer required at their post.

Kaponiers in permanent works are large casemated masonry buildings, mounting one or two tiers of guns; but in field-works they are only constructed of timber, and consequently are liable to be destroyed by the enemy's pitching fire, unless the roof is sunk well below the crest of the glacis. To do this, and at the same time retain sufficient thickness of roof and head-room for the defenders inside, it is in many cases necessary to sink the floor below the level of the bottom of the ditch. This brings the loopholes close to the ground, and exposes as little as possible of the stoccade timbers, but has the disadvantage of

being liable to be flooded in wet weather; and, moreover, the loopholes, if very low down, may be masked and rendered useless by the earth dislodged from the escarp by the explosion of the enemy's shells forming mounds in the ditch.

Reverse or counterscarp galleries are similar in construction to kaponiers, but are placed under the glacis, their front wall being the counterscarp of the ditch (Fig. 43). They have the advantage of being more secure from the enemy's fire, but have no means of communicating or receiving assistance during the fight, and the retreat of their defenders would inevitably be cut off should the enemy gain possession of the works.

It must be understood that in permanent works where this method of flank defence is adopted, this latter defect does not exist, as a passage is usually constructed under the ditch communicating with the interior of the inner work.

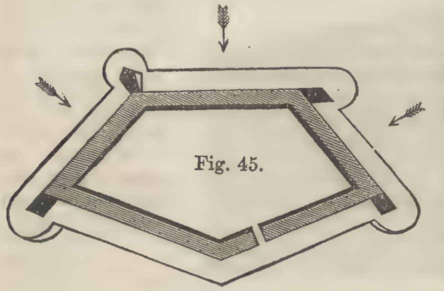


Fig. 45.

In redoubts whose ditches are twelve or thirteen feet below the crest of the glacis, it is not necessary to sink the floor of the counterscarp gallery below the level of the ditch, as that height is sufficient to admit of seven feet head-way inside, as well as a thickness of roof of five feet (Fig. 44). To protect the timbers of the front of the gallery from the splinters of shells bursting near them in the ditch, a small excavation should be made at the bottom of the ditch, and the earth from it piled against them as high as the bottom of the loopholes (Fig. 44). This excavation, if provided with pointed stakes, will assist the defence, by preventing the enemy from closing with the loopholes from outside.

The position of these defences with reference to the direction of the enemy's fire is very important, and can only be determined by the special conditions of each case. Field-works, even when closed, and therefore capable of resistance in any direction, are really always part of some general line of defence against an enemy advancing in certain known directions; the sides, therefore, most liable to attack can generally be determined on when the plans for the work are drawn up, and the kaponiers or galleries placed accordingly. The accompanying diagrams (Figs. 45 and 46) show the way in which either of these types of defence may be applied to flank the ditches of an ordinary pentagonal redoubt; but it is by no means necessary that the whole of the ditches need be flanked in the same manner, a combination of the two being frequently advisable.

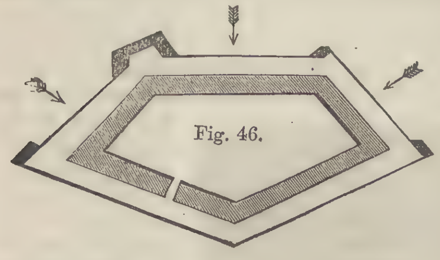


Fig. 46.

The defence of a field-work may be rendered more obstinate by the construction of a small central work within it, which is capable of being defended after the main work has fallen. Such a work is called a *reduit*, and may be either a small earthen redoubt or a loopholed building, with a bomb-proof roof similar in construction to a kaponier. In the former case the parapet of the reduit should be somewhat higher than the outer work, to prevent the enemy from seeing into it when standing on the parapet of the main work; but in the latter the block-house (as such a reduit is called) should be as low as possible, to protect the walls from fire, while its loopholes command the whole interior of the main work. Reduits are useful in affording protection to the stores and reserves of the garrison, and either contain or (if block-houses) are themselves the barracks for the troops. Reduits of permanent forts are large casemated buildings, placed near the gorge of the works, and containing the principal magazines. They also communicate directly with the kaponiers and galleries of the outer work, and have generally ditches and flank defence of their own.

FARMING AND FARMING ECONOMY.—I.

By Professor Wrightson, Royal Agricultural College, Cirencester.

Rural economy has from the earliest times been divided into agriculture proper (*agricultura*) and the management of stock (*pastio*); the first having reference to the cultivation of the ground for crops, and the second to the pastoral occupations of breeding and rearing cattle. In treating of farming and farming economy, however, we shall find that on the greater number of farms these two branches are united, giving rise to what is conveniently named "mixed husbandry." Under the common name of "agriculture" the management of both "stock" and "crop" is usually included, and both classes of produce will occupy our attention in the following series. The importance of this art is most thoroughly seen when we reflect upon its universality, the many forms in which it meets us throughout the world, and its direct and indirect effects upon the well-being of the human race. The culture of plants and domestication of animals render the necessaries of life abundant, and a large population possible. The more, indeed, we reflect upon agriculture, the clearer do we see its vast importance. We recognise in it the underlying tissue binding the members of a nation into one; the source of food, of clothing, and of luxuries; and an employment for the greater part of the human race. It is with such a subject we have now to deal, and at the outset it would be well to settle how we may best consider it. In the first place, we must restrict ourselves to English, or at most to British farming, and that principally of our own time. Such attention we must give to the history of the art as will be necessary to make our own customs and notions intelligible; and in bestowing it we shall see that while generation after generation have profited by a long experience, they have also handed down to us obsolete ideas which to this day shackle us.

The history of agriculture appears to have been affected by three distinct but parallel influences. First, the law of landed property, rendering the owning and holding of land possible, conferring power upon the owner, and greater or less security upon his dependants. Secondly, the accumulated experience of the art, aided from without by other branches of knowledge. Lastly, we have the influence of the growth around agriculture of numerous industries formerly unknown, in turn checking or encroaching upon it, or stimulating it by home and foreign competition of various kinds to fresh exertions. We shall glance briefly at the first two classes of causes; but the last extends over too wide and varied a field for present consideration.

The most casual observer of the economical condition of land as a property in this country will note that for the most part it exists as large estates owned by our aristocracy and gentry, and farmed by tenants removable at the will of the owner, or, more strictly, superior tenant, commonly called owner. Lastly, there is the labourer, on whom ultimately falls the burden of actually cultivating the land and securing its produce. The "owner" is entitled to rent, "which implies a return in service, corn, cattle, and money from the land demised" (Bayldon). He also retains the right of re-entry, after legal notice, and certain rights as to woods, mines, game, etc., which need not now detain us. The tenant, usually termed the "farmer," is, under certain restrictions or limitations, allowed to apply his capital in cultivating the land, and is entitled to the surplus profits, after rent and other burdens have been paid. He has, however, too frequently no permanent interest in the land, and is liable to eviction at six months' notice from the landlord or his agent. The labourer has no legal interest in the land, but is entirely dependent upon the farmer, for whom he works at weekly or daily wages.

To this threefold system of landlord, tenant, and labourer, the term "farming" properly belongs. This word is now for the most part used to denote the occupation of agriculture, and the estate or land itself is usually spoken of as a "farm." The occupations of agriculture and farming are, however, by no means synonymous terms, since farming presupposes the pay-

ment of rent, and involves tenancy. "Farm, or *feorme*," writes Bayldon, in his "Rents and Tillages," "is an old Saxon word, signifying 'provisions,' because anciently the rents were paid in produce, and were altered by the introduction of money. A farmer, or *firmarius*, was one who held his lands upon paying a rent, or *feorme*." When a landlord cultivates his own property he is not strictly speaking a farmer, although in ordinary language he may be so designated; and, again, by the payment of a fixed rent or share in the profits, the farming system has been introduced into mining, tax-collecting, and other occupations altogether unconnected with the cultivation of the soil. The agriculture of this country is for the most part carried on by a system of farming or hiring—a system springing naturally from the great extent of landed estates which could not well be cultivated by their owners, and are therefore let to tenants. How far the system of tenant-farming is the best for the land and the community is a question upon which much may be said; but we may safely conclude that it is the only system compatible with the large estates into which England is divided, and that it has many solid advantages. To the landlord it gives an assured revenue, and to the tenant it offers a fair profit upon capital invested. The labourer is, however, less fortunate, and there is reason for thinking that the system of letting land places him in an unsatisfactory position; the tenant scarcely having a sufficiently permanent interest in the land to warrant him in expending capital on labourers, while the landlord, so long as his rent is paid, has no direct or pressing reason for attending to the requirements of the labourer.

Familiar as our system of landowning and hiring is, it had a commencement and rise which may be traced with the aid of history. In the fourteenth century traces are met with of an older system of landed property, which at that time had well nigh disappeared. We refer to the old Teutonic "mark," or "township," with its three constituent parts—"the 'common mark' (the *folc-land* of the Anglo-Saxons), owned jointly by the community; secondly, the 'arable mark' (*feldmark*), cut out of the common mark, and apportioned in equal lots to the members of the community (the Anglo-Saxon *boc-land*); and, lastly, the 'mark of the township' (*dorf, thorp, villa*), also divided into individual lots, and individually appropriated."*

This primitive distribution of land had at the period specified ceased, and the lord of the manor had obtained an overlordship or suzerainty over those who had formerly been his equals. Thus, according to Professor Rogers, in the thirteenth and fourteenth centuries "the parish or manor was divided into four portions. First, the lord held, together with his feudal rights over the whole, except the glebe of the parson or impropriator, a demesne, which he cultivated by his bailiff; secondly, there were the small estates possessed by the freeholders, who paid quit-rents; thirdly, there were the tenements and lands of *villains, bordarii*, or *cotarii;* and, lastly, the waste or common, over which all tenants had right of pasture, and sometimes of turf." The freeholder was, in fact, a farmer at a perpetual lease, and is the predecessor of the freeholders of the present day, who still pay quit-rents to the lord of the manor. Next, and below the free tenants in rank, are the *nativi*, or *villains*, and the *coterelli*, or *cotarii*, holding their tenancies at agricultural services, these services being commutable for specified sums of money. The position of the *villain* was servile, and in many respects unfortunate. They are the forerunners, not of tenant-farmers, but of copyholders, and could not readily be evicted by their lords at the time under consideration.

Previous to this time, as already stated, the lord's demesne had been cultivated by means of a bailiff, a custom generally discontinued after the Plague, which first devastated the country in 1348. Professor Rogers states that Merton College, Oxford, let their estate at Ibstone, in 1300, for thirty-five years, and that after the Plague most of the college estates were let; also, that about the year 1381 the leasing of land became general. At this time the freeholder held an independent and safe position, and even the copyholder, or tenant in villenage, was a permanent tenant, whose land could not be entered by the lord. We may therefore fairly date the custom of letting land, and the rise of the important body of tenant-farmers, from the commencement and middle of the fourteenth century.

The mass of peasant proprietors, comprising *socage* and *villain*, or free and copyhold tenants, has been steadily absorbed by the purchase of their lands by the great landowners, so that at the present day they have, as a class, almost disappeared; and in the place of the lord of the demesne cultivating his own estate through his bailiff, and surrounded by a more or less free tenantry, we have the modern economy of landlord, tenant, and labourer.

In contrasting modern farming with the cultivation of the thirteenth and fourteenth centuries, we become conscious of the immense improvement which has gradually taken place. At that early date wheat, barley, oats, rye, beans, peas, vetches, etc., were all in ordinary cultivation, and the usual domestic animals were present as live stock. There is also an unexpected uniformity of management or practice in estates far remote from each other, which suggests a freer means of communication between various parts of the country than might have been supposed to exist. Root-crops were, however, unknown, and winter feeding of stock was therefore impossible. The so-called "artificial" grasses and clovers (seeds) had not yet appeared; implements were rude, and manure was sparingly employed. The imperfect method of cultivation is best shown by the small return in proportion to the seed sown. The amount of seed approximated to that now used by many farmers—namely, two bushels of wheat, rye, beans, peas, and vetches, and about four bushels of barley, bere, and oats. The records of Merton College, Oxford, which have been so ably edited by Professor Rogers, supply exact information as to the yield of grain upon various estates during the season 1333-4. "Wheat at Maldon returns about four times the seed; at Leatherhead, less than three; at Farley, less than four; at Cambridge, about four; at Wolford, more than eight times; at Cuxham, about four and a half times; at Holywell, nearly eight times; at Basingstoke, about three times the quantity sown." An average crop of wheat at the present day has been variously estimated, but twenty-eight bushels per acre is probably very nearly correct over the whole of England, while thirty bushels is commonly looked upon as a fair crop. We see, then, that modern culture has greatly increased the amount of produce per acre in the case of wheat, and the same is true with regard to other crops.

In tracing the history of the various improvements introduced into British agriculture we shall do little more than indicate the period at which they occurred. "Great clover," and probably turnips, were introduced by Sir Richard Weston, about 1645. In the third edition of Blythe's "Improver Improved" (1662), both clover and turnips are noticed, and a considerable share of attention is bestowed upon drainage and other improvements. In Haughton's "Collections on Husbandry and Trade," a periodical commenced in 1681, occurs the first notice of sheep being fed upon turnips upon the land. It was about this time that the potato began to attract the attention of agriculturists, although previously known as a garden vegetable. At the beginning of the eighteenth century, clover and rye-grass appear to have been sown together, and cut as green food; and at this period Jethro Tull perfected his system of drill husbandry and horse-hoeing. Turnip husbandry also appears to have greatly extended in the middle and towards the close of the last century, thus preparing the way for the maintenance of the improved races of domestic animals now about to appear. About the year 1755, Robert Bakewell, of Loughborough, Leicestershire, turned his attention to sheep and cattle breeding, and introduced the famous Leicester or Dishley sheep, and the "long-horn" race of cattle. Subsequently Charles Colling (formerly a pupil of Bakewell) and his brother Robert brought out the celebrated short-horn race, by improving the native cattle of North Yorkshire and South Durham (the Teeswater breed) by careful selection. The present century has been remarkable in the progress of agriculture. It is during this period that agricultural societies have been founded, and have arisen to their present importance; that agricultural colleges have been opened, that steam has been applied to cultivation and thrashing, that chemistry has revealed the true nature of foods and fertilisers, and that a steady improvement has taken place in live stock and cultivated plants.

For fuller information on the above interesting points relating to ancient agricultural customs the reader is referred to Professor Rogers' "History of Agriculture and Prices" (Clarendon Press, Oxford), and Maine's "Village Communities in the East and West" (John Murray).

* Morier, "System of Land Tenure in Various Countries: Germany."

OBJECT DRAWING.—III.

FIG. 11 represents a cube placed on the left side of the spectator; and on this cube rests a square pyramid.

Having already given the elementary principles on which the view of the cube is based, it is only necessary here to refer to the pyramid which is drawn separately in Fig. 12.

Let A B be the side of the base of the object. From A and B draw lines to the point of sight; and it will be clear that portions of these lines will be the sides of the square, which, being at right angles to the plane of the picture, converge to the point of sight.

The line C D will give the back line of the figure, which thus represents the "plan" of the pyramid, or the piece of ground on which it stands.

The exact position of the apex or point is next to be considered. Now, although in the mere elevation (that is, the view in which only the front of the object would be shown) the apex would be immediately over E, the middle of the base of the isosceles triangle, this is not the case when the eye is moved towards either side of the object; for it must be remembered that the apex is *not* over the middle of the *side*, but over the middle of the *square* forming the *base*.

Fig. 11 is only over the intersection of the diagonals of the cube, because the pyramid is placed so that the edges of its base correspond exactly with the edges of the top of the cube. Other circumstances will be considered in future lessons.

Fig. 14 is a cube on which rests a pyramid, the apex of which is not over the centre of the top of the cube. Having sketched the cube as in former lessons, draw the line A B representing the front edge of the base of the pyramid.

As the pyramid is to be represented as if moved forward, this line must of course be drawn in front of C D, the edge of the cube, and although it would in reality be the same length, it must be longer than C D, being, in fact, the most prominent line in the picture. You will understand this if you refer to the cut in Lesson I, in which D E represents the line on which the picture-plane stands.

Now, if you place such a plane in front of the present subject, and gradually move it nearer and nearer to it, the first part at which it would touch would be the line A B.

From A and B draw lines to the point of sight; for although the pyramid has been moved sideways and forward, its edges have been kept parallel to those of the cube, and the lines A E and B F in the model are at right angles to the plane of the picture. Next draw the line E F, which completes the base of

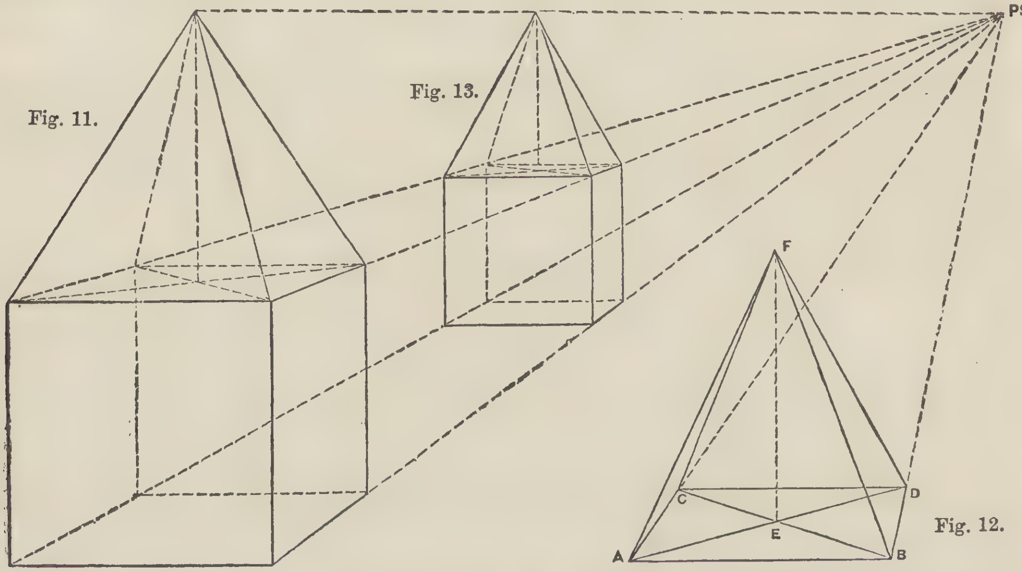


Fig. 11. Fig. 13. Fig. 12.

Therefore, having sketched the figure A C D B, draw diagonals the intersection of which, E, will clearly give the centre of the base. On this point erect a perpendicular; mark on it the apparent height F, and draw F A, F B, F D; the line F C may be lightly drawn, which will give a transparent appearance to the drawing.

Having thus studied both the objects of which Fig. 11 is composed, it will be a comparatively easy task to draw the two when combined.

Draw the cube as already shown, and as the base of the pyramid in the present case corresponds in size with the sides of the cube, draw diagonals in the upper surface, and, as in Fig. 12, erect a perpendicular on which the apparent height is to be marked; the object (Fig. 11) is then to be completed as before.

The student is advised in most cases to sketch the objects as if transparent. These interior lines may, of course, be rubbed out before shading; but they will be a great guide in testing the correctness of the general form, and will materially assist in finding the distant points of the figure and the position of the objects in relation to each other.

Fig. 13 is the same view, representing the object when removed from the immediate foreground. In this view the object is supposed to have moved backward in a direct line from Fig. 11, as if guided by a tramway; the student will thus be able to account for the diminution in size.

It must be pointed out, that the apex of the pyramid in

the pyramid. In the quadrilateral A B F E draw diagonals; at their intersection erect a perpendicular equal to the apparent height, G, of the object; and finally draw G A, G B, G E, and G F.

Fig. 15.—This is a cube resting on one of its edges, whilst another touches the cube, Fig. 14.

Now it is necessary to bear in mind, that although this cube rests on one edge only, the plane of the side A′ B′ C′ D′ is parallel to the picture. To prove that this is so, place the cube, in the first instance, on one of its sides, the face A′ *b c d* being parallel to the picture, as in Fig. 14; raise the object at *b*, until the edge *d* rests against the side of the cube (Fig. 15 at D′). It will then be evident that the object has merely rotated on A from left to right, but that the surface remains parallel to the picture-plane as before.

The shape of the front therefore remains unaltered—a perfect square—but resting on the angle A′ instead of on the side A′ *b*.

To draw this object, draw the line A′ D′, carefully observing (1) that it must be of the length of the side of the cube (Fig. 15), the cubes being equal, and (2) that it slants in the degree required; the line A′ D′ forms the hypothenuse of the right-angled triangle A′ E D′, and by comparing the angles at A′ and D′ in your drawing with those formed by the meeting of the two models, you will soon discover whether the cube is sufficiently inclined.

On A′ D′ draw the square A′ B′ C′ D′, which will give the face of the cube in the position required.

Reverting to the original cube drawn in dots, it will be seen

that the edges $b\,b'$ and $c\,c'$, being at right angles to the picture, converge to the point of sight, and this will still be the case, for though the edges of the cube have altered in *position*, they have not altered in *direction*, but still run directly from the foreground into the distance at right angles to the plane of the picture. Therefore from A′, B′, C′, D′ draw lines to the point of sight.

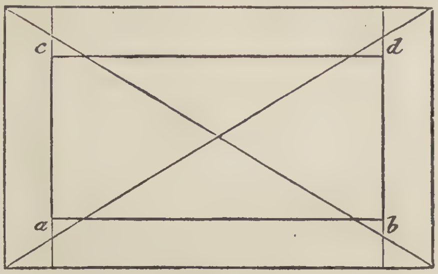


Fig. 17.

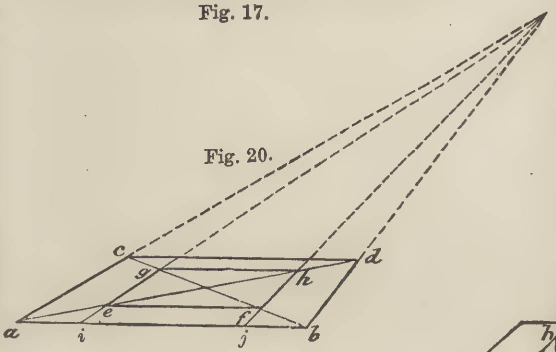


Fig. 20.

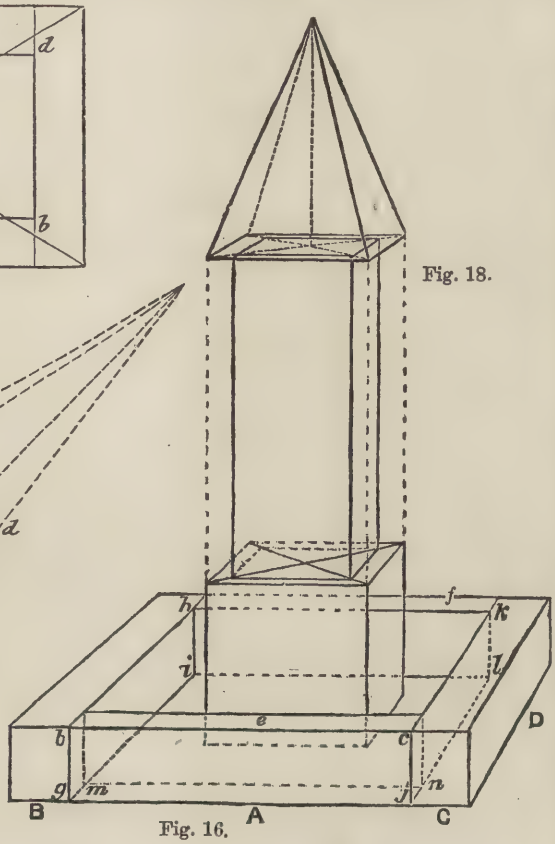


Fig. 18.

Fig. 16.

The line drawn from D′ will cut the distant perpendicular of Fig. 14 in E′, and as the cubes are equal, this will determine the depth of the distant sides; therefore from E′ draw a line parallel to D′ A′, cutting a line drawn from A′ to the point of sight in F. Also from E′ draw a line parallel to D′ C′, cutting a line drawn from C′ to the point of sight in H. From F draw a line parallel to A′ B′, cutting a line drawn from B′ to the point of sight in G. Draw G H, which will complete the object.

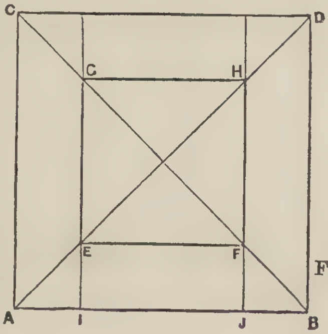


Fig. 19.

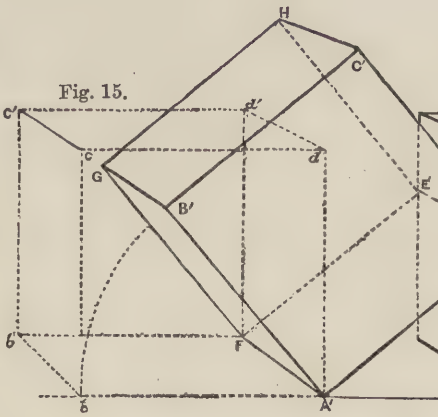


Fig. 15.

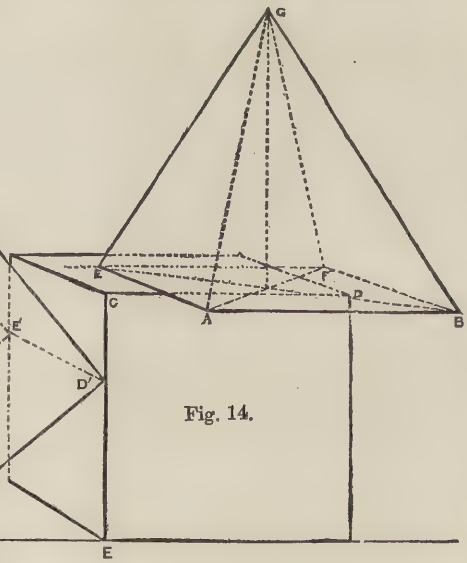


Fig. 14.

Fig. 16.—This figure is composed of four equal blocks, or solid oblongs; they are equal in length, and since they are not mitred at the angles, the figure they form is not a square. To make this clear, let us suppose that the blocks are 12 inches long, and that their thickness is 3 × 2 inches, and that they are all resting on the side, which is 2 inches wide. Now, placed as they are in the group, A will be 12 inches long, whilst the end of each of the blocks B and C, placed at the side, is 2 inches. Thus the width of the front will be 16 inches, whilst the length of the side D is only 12 inches, the length of the block.

In beginning to draw the object thus formed, sketch the entire front, carefully observing the proportion of the blocks.

Next draw the view of the upper surface of the whole object, treating it as a complete block. This surface, it will be remembered, must not be as wide as if the figure to be represented were a square; the side D is then to be added.

Now from b and c draw lines to the point of sight, in order to represent the inner edges of the two side blocks. If the object were a square, diagonals would now be drawn in the complete quadrilateral representing the top, and the points where b and c cut these would give the positions of the corresponding lines of the two blocks which are parallel to the picture. This has already been referred to in previous lessons, and will be further shown presently.

This method would not hold good in reference to an oblong, for it will be seen on reference to Fig. 17, that when the four pieces are placed as in the group, the points a, b, c, d do not fall in the diagonals.

In object drawing, therefore, the student will, in this case, be called upon to exercise his judgment as to the width of e and f. It may, however, guide him to be reminded, that in the present view the width from front to back is considerably diminished. The width from left to right retains its true dimensions in the front, and is but slightly decreased at the back. It will be clear, then, that the width of e must be rendered less than

that of b and c, and that f, being in the distance, must be still further diminished.

From g draw a line to the point of sight, and from h draw a perpendicular. This will give the point i. Then draw a similar line from j to the point of sight, and a perpendicular from k. This, again, will give the point l, and as $k\ l$ is the angle at which the back and right side meet, the line $k\ l$ should be equal to $h\ i$, and thus a horizontal line drawn from i should meet l. The rest of the lines required to complete the transparent appearance of the drawing are now to be added; this is necessary since the cube is to be placed in the middle of the vacant space, and it is important to know its position, for if the front line of the base of the cube were placed too far back, it will be clear the cube could not stand in the space, nor can the height of an object which is partially hidden be truly ascertained, unless the obstacles which obstruct the complete view are imagined to be transparent, so that the whole object may be sketched in.

The plan of the cube is now to be sketched in the space $i\ l\ m\ n$, observing that there must be a clear space left all round it, the width on the right and left side being more than that at the front and back. The square for the front is then to be drawn, and the whole cube will then be easily completed.

Fig. 18.—An oblong block, the ends of which are square, stands on the cube. The height of the block here represented is 12 inches, its width being 4 inches. The top of the cube is 6 inches, and thus in the model a margin of 1 inch is left all round. The method of rendering this in a drawing has been before alluded to, but is here given as a separate study, in order that it may be more clearly understood.

Let A B D C (Fig. 19) be a square in which a smaller square, E F H G, is inscribed. It will be seen that the angles of the inner square are on the diagonals of the outer one.

Now, in making a perspective sketch of this figure, draw the line $a\ b$ (Fig. 20) equal to A B, and having drawn lines to the point of sight, draw the back line of the figure, $c\ d$.

Through the points E, G and F, H (Fig. 19) draw lines meeting A B in I and J. From a and b (Fig. 20) set off $a\ i$ and $b\ j$, equal to A I and B J in the previous figure; then from i and j draw lines to the point of sight, which, cutting the diagonals in e, g and f, h, will give the points of the smaller square.

This method is then to be applied in the upper surface of the cube in Fig. 16, and perpendiculars having been drawn from the angles of the inner square, the oblong block may be completed.

A pyramid is now to be placed upon this group, the base of which is larger than the end of the block on which it stands. The lines forming the base of this pyramid being parallel to the edges of the top of the cubical block, the diagonals will coincide.

Now let us imagine $e\,f\,g\,h$ in Fig. 20 to represent the top of the oblong block.

Draw diagonals, and produce them beyond the angles of the figure. Then draw the line $a\,b$ at such a distance in front of $e\,f$ as may be required. From a and b draw lines to the point of sight, cutting the produced diagonals in c and d. Join $c\ d$, and this will complete the figure.

In the present study, the base of the pyramid is equal to the top of the cube; therefore, when the diagonals of the top of the oblong block have been produced, perpendiculars raised from the angles of the cube, as shown in the figure, will give the points to which the lines are to be drawn. The cube and pyramid are those shown in Fig. 11, in which it will be seen that the one exactly covers the other; therefore it will be evident that when the pyramid is raised, so long as the edges are kept parallel to those of the top of the cube, the angles of the upper object must be immediately over those of the lower one.

A perpendicular is now to be raised on the intersection of the diagonals; and on this the apex of the pyramid is to be fixed. Lines drawn from this point to the angle of the base will complete the object.

For convenience of reference the enclosure of blocks, the cube, upright oblong block, and surmounting pyramid, have been considered as forming two figures numbered respectively Figs. 16 and 18. It will be useful for the pupil to study and make drawings of these figures separately as well as in combination. In either case the same method must be pursued.

SEATS OF INDUSTRY.—XII.

DUNDEE.—II.

BY WILLIAM WATT WEBSTER.

THE story of the introduction of jute into manufactures is, perhaps, the most interesting episode in the industrial history of Dundee, which has almost monopolised the working of this fibre, at all events up to the present. Dundee has been called "Jutopolis" by some of her citizens, and her claim to the title cannot be disputed. Towards the end of the last century the East India Company sent specimens of a variety of fibres to this country, in order to ascertain whether any of them could be used as a substitute for hemp, and in the lot was included a quantity of jute, which, however, attracted no attention for a considerable time after its arrival. It was at Abingdon, in Oxfordshire, a town noted for sacking and twines, that this fibre is understood to have been first spun into yarn and worked into carpets. In the year 1822, Mr. Thomas Neish, a Dundee merchant, received a small consignment of jute from London, but failed in his efforts to induce the manufacturers to make an attempt to spin it; and after the parcel had been kept for a few years, it was sold to be made into door-mats. About two years later a few bales of the new fibre were sent to Mr. Anderson, a Dundee manufacturer; but although he persuaded his mother, who was an expert at the work, to try to spin it, the experiment was a failure, and all that Mr. Anderson succeeded in producing from the material was a coarse yarn that could be partially used for sacking. In 1832 Mr. Neish got another consignment of jute, which was again offered to the manufacturers and rejected. At last, however, he succeeded in inducing Messrs. Balfour and Meldrum to experiment with the new material, and a successful result having been attained, the foundation of the Dundee jute trade was laid. During the first three years after its introduction, jute was uniformly mixed with flax and tow; but by 1835 pure jute yarn was spun and sold. At that time the fibre could be bought for £12 per ton, whereas now its price ranges from £19 10s. to £26, according to quality. In a review of the local trade for 1870, the *Dundee Advertiser* gives the following statistics of the imports of jute into Dundee for the five preceding years: the figures are both interesting and instructive:—1865, 71,702 tons; 1866, 52,179 tons; 1867, 63,676 tons; 1868, 58,474 tons; 1869, 80,135 tons; and 1870, 81,600 tons. In 1868, 5,437 tons of jute were imported into Dundee direct from Calcutta, and in 1869 the quantity brought into the port had risen to 27,850 tons. Several of the mill proprietors of Dundee are the owners of the vessels in which their jute is imported, and the "East Indiamen" belonging to them form a splendid mercantile fleet. "The employment of steamers to carry the jute *viâ* the Suez Canal," says the newspaper already quoted, "is a new feature in the trade, which has been called into requisition by the small stocks here, but bids fair to displace to a large extent sailing vessels *viâ* the Cape of Good Hope. The extra cost, after making allowance for towing in, insurance, and interest, is scarcely twenty shillings per ton more than by sailing vessels *viâ* the Cape." Regarding the qualities and kinds of the fabrics produced from jute at Dundee, the deliverance of the jury on jute goods exhibited at the International Exhibition for 1862 may be cited:—"It is in Scotland exclusively where goods made from jute represent a large branch of industry. This very cheap raw material is employed there, either pure or mixed, to make ordinary brown cloth, but more especially sacking, packing-cloth, and carpets. The jute yarns used for carpets are of the richest and most varied colours, and are sometimes used with cocoa-fibre. Even the Brussels or velvet carpet is imitated with success, in appearance, if not in durability." The prices of jute carpeting varies from about 6d. to 1s. 4d. per yard. Jute fabrics are exported to the United States, France, Germany, Spain, and several other European countries, and recently a demand has sprung up in Russia for certain of the coarser qualities.

The most extensive manufacturing establishment in Dundee is that of Messrs. Baxter Brothers and Co. One of the chief partners of that firm was the late Sir D. Baxter, Bart., of Kilmaron—a gentleman distinguished alike for enlightened philanthropy and success in business. Besides a variety of smaller benefactions, Sir David founded several scholarships and endowed a chair of civil engineering in the University of Edinburgh; and he and his sisters, with wonted liberality, presented

the town of Dundee with a public park, thirty-eight acres in extent, which cost £50,000, including the embellishments and an adequate endowment for its maintenance. Messrs. Baxter Brothers consume about 7,000 tons of flax annually, and are by far the largest manufacturers of that material in the world. In the spinning department of their works there are some 22,000 spindles, and in the weaving rooms there are about 1,200 power-looms, the motive power being supplied by twenty-two steam-engines, with an aggregate of 750 horse-power. From 4,000 to 4,500 persons are employed by this firm, which produces annually about 20,000,000 yards of various descriptions of cloth, navy sailcloth being the principal fabric they manufacture, and the British navy their principal customer. Excellent school-rooms are connected with the works, to which all the employés have free admission, and a library is also at the service of the workers. The schools have been in existence for upwards of forty years, and the salaries of the master, mistress, and paid monitors, as well as every other expense, have been and continue to be defrayed by the firm.

Messrs. Cox Brothers are probably the next most extensive manufacturing firm in Dundee, about 4,300 persons being employed at their works, which occupy eighteen acres of ground, and are situated at Lochee, one of the suburbs of the town. This firm have agents in Calcutta, and import their jute direct. All the operations of spinning, bleaching, dyeing, weaving, calendering, and packing are completed within their works, which are adorned with a very elegant chimney stalk 300 feet high, and 35 feet in diameter at the base. Messrs. Gilroy Brothers and Co. employ 2,000 persons in their mills, which have a frontage of about a thousand feet, and are the most imposing mill buildings in the town or its neighbourhood. Among the other manufacturing firms in Dundee may be mentioned Messrs. A. and D. Edward and Co., who employ 3,300 persons; Mr. O. G. Miller, who owns five mills, and employs 2,000 work-people; Messrs. J. and A. D. Grimond, and Messrs. Thomson, Shepherd, and Briggs. About ten miles from Dundee, and close to the village of Carnoustie, near the mouth of the Tay, are situated the works of Messrs. James Smieton and Sons, which for various reasons deserve special mention in this paper. This firm only employ about 600 persons, but they have usually some eighty different kinds of cloth in the looms at one time, and they manufacture some five hundred various patterns and fabrics out of flax, tow, and jute. The yearly product amounts to about 5,000,000 yards, and consists principally of "drills," "paddings," and "Russian sheetings" for the United States, West Indies, and Mexico; but "checks" and "stripes" are also made in great variety. It is not, however, for the variety of the fabrics that these works are most noteworthy, but for the institute which the proprietors built in 1864, at a cost of £2,000, and maintain at an annual outlay of £300, for the benefit of their work-people. This institute comprises a fine hall—furnished with a pianoforte and harmonium—class-rooms, library, reading-room, etc., and it has to be added that Messrs. Smieton and Sons have built about eighty dwelling-houses for the accommodation of their employés.

The progress of the port of Dundee has been as remarkable as the progress of her manufactures, and the population has increased in a corresponding ratio. If we may trust Robert Edward, minister of Murroes, who wrote a highly panegyrical and rhetorical description of Dundee in 1678, at that date Dundee was a town of no mean consequence, and had fairly started on a commercial and industrial career. "At Dundee," says this divine, "the harbour, by great labour and expense, has been rendered a very safe and agreeable station for vessels, and from this circumstance the town has become the chief emporium not only of Angus, but of Perthshire. The citizens here (whose houses resemble palaces) are so eminent in regard to their skill and industry, that they have got more rivals than equals in the kingdom." But in 1821, nearly a century and a half later, the population of Dundee had only grown to 30,575, and in 1815 there were but 157 vessels belonging to the port, registering in all 15,275 tons, while 66 vessels entered inwards with cargoes from foreign ports, having an aggregate of 10,620 tons register, and three vessels cleared outwards with cargoes for foreign countries. From the latter date the commerce and population of Dundee have steadily increased, and are still rapidly augmenting. In 1860, 3,130 vessels, representing a total of 396,919 tons burden, were entered and cleared at the port; while in 1861 the population had increased to 90,425, and it has risen during the last decade to about 123,000. It is estimated that since 1815 upwards of £600,000 have been expended on the harbour works, and a project for further harbour improvements, involving an expenditure of about half a million sterling, has been under discussion for several years. Among the minor industries of the town may be mentioned ship-building, machine-making, sugar-refining, and the manufacture of kid gloves, marmalade, and confections.

During the present century the trade of Dundee has passed through many vicissitudes, having been affected for good or for evil by most of the great political events that have occurred throughout the world. The Crimean war brought prosperity to the town, but the American war of Nationality, as the author of the "Biglow Papers" has so happily designated the struggle between the Northern and Southern States of the American Union, may be said to have flooded the town with wealth. Since that very recent date extensive additions have been made to the factories, and mansions and villas have been built in profusion in the suburbs, and in the neighbouring villages on both sides of the Tay. Great improvements have also been effected in the town within the past twenty years, new streets having been formed, and old thoroughfares straightened and widened; but Dundee still abounds in narrow, crooked streets, and a considerable portion of the population still occupy closes where they are "cribbed, cabined, confined," and it would not, perhaps, be a great exaggeration to say that they are "coffined" there as well. But the inhabitants of Dundee, although justifiably proud of the eminent position that the town has attained, are keenly sensible of its defects, and bent upon remedying them. A healthy spirit of emulation pervades the community, which is at once the promise and the guarantee of further progress. The Town Council of Dundee consists of a provost, four baillies, and sixteen councillors, who also act as Police Commissioners; and for years this body has fairly reflected and given effect to the public-spirited enterprise of the citizens. The interests of the staple trade of Dundee are sedulously watched by a Chamber of Commerce, which also criticises and sometimes opposes projects started by the public boards, and in this way it occasionally renders an important service to the inhabitants at large, as well as to the manufacturers. Within a few years a free library has been established in Dundee; the gas works have been purchased for the community; and a splendid esplanade has been constructed on the bank of the river. Dundee abounds in charitable institutions, and contains a very large number of ecclesiastical edifices. The most notable of the former is the Morgan Hospital, a splendid building, in the Scotch baronial style of architecture, which was erected and endowed with money bequeathed to the town by a native who made his fortune in India; and by far the most celebrated of the latter is the ancient tower of St. Mary's Church, commonly called the "Old Steeple," which is said to be nearly eight hundred years old, but which more probably dates from the middle of the fourteenth century, as it is in the Decorated Gothic style, which appears to have been first introduced into Scotland during the reign of David II. Among recent additions to the public buildings of Dundee, the Albert Institute deserves mention. It originated in a desire to perpetuate the memory of the Prince after whom it has been named by furthering the objects he had most at heart. The Free Library is deposited in this building, and it is proposed that wings should be erected for a public museum and picture gallery. In 1831 the Government, at the request of the inhabitants, granted the town a resident sheriff-substitute, and the Dundee court has for many years been more important than that of the county town. A large proportion of the manufacturers of Dundee have raised themselves from the humbler ranks of industry, and there are few gentry and nobility connected with the town and neighbourhood. Although the merchants and manufacturers possess an elegant Exchange, the majority of them prefer to transact their business *al fresco* on the plain stones of the Cowgate, as their predecessors have done for generations. There are many Irish in Dundee, the majority of whom are Roman Catholics. The condition of the working people generally will compare favourably with that of any other manufacturing town in Great Britain. Dundee is, in short, a fine specimen of a thriving industrial town.

BUILDING CONSTRUCTION.—XVII.

ROOFS (*continued*).

HAVING the advantage of the co-operation of the heads of various Continental technical schools, we are enabled to introduce several examples used in those institutions, some of which are well worthy of our careful study as well as imitation, and from all of which most important instruction in useful methods of constructing roofs may be derived.

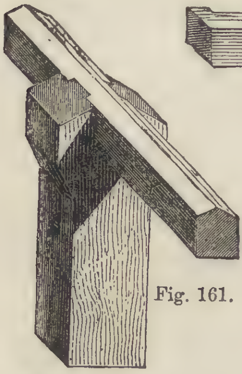


Fig. 161.

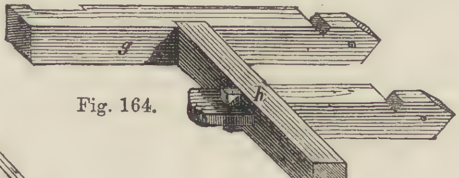


Fig. 164.

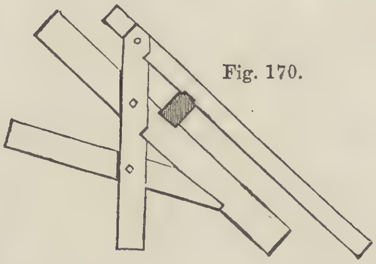


Fig. 170.

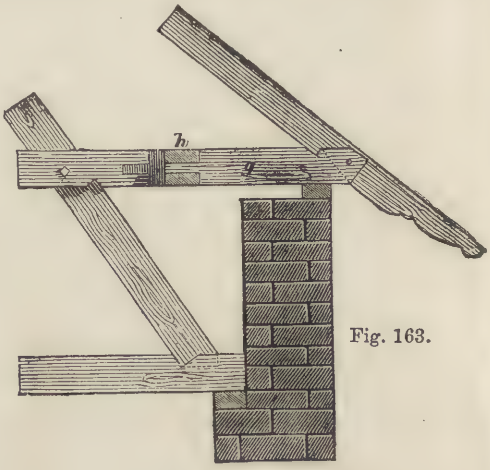


Fig. 163.

Fig. 165.

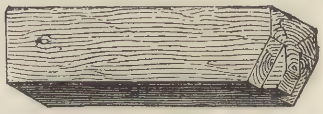


Fig. 162.

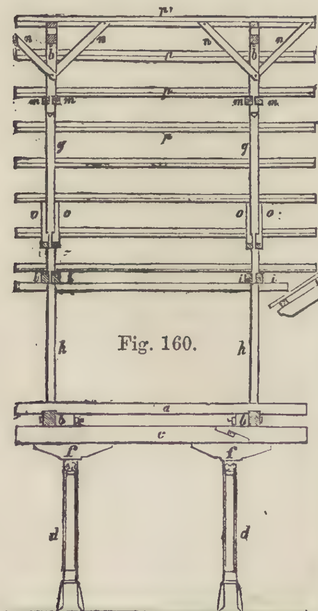


Fig. 160.

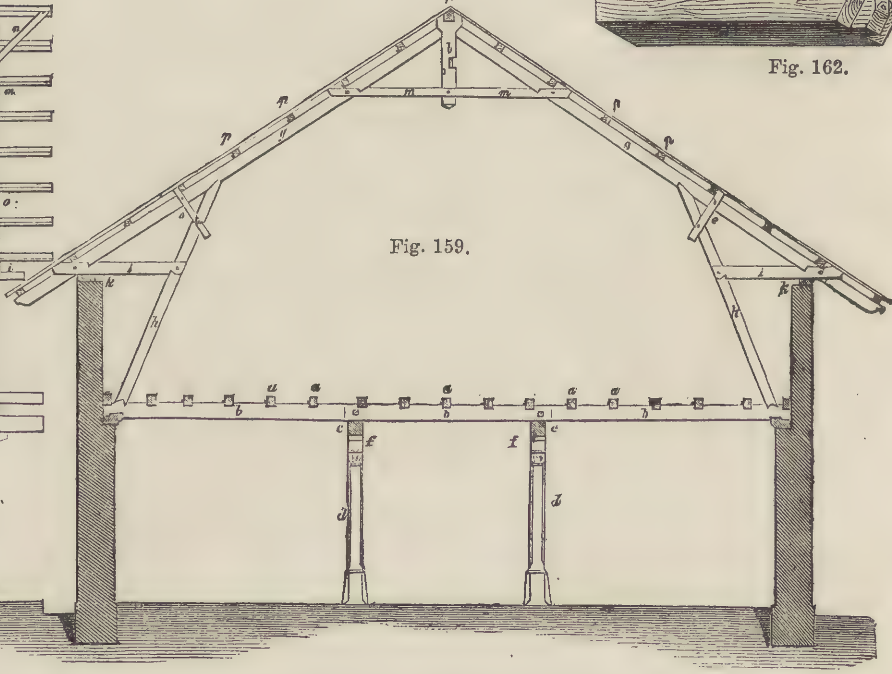


Fig. 159.

Fig. 159 is the transverse section of a German agricultural building, the lower part of which is used as a stable or cattle-shed, and the upper floor as a loft for storage of hay, grain in the sheaf, etc.

It will be remembered that the great object to be constantly kept in view in designing a roof is that its weight must not press *outward*, but *downward*, and this object is best attained by carrying the bearing as low down as possible.

In this example the walls are doubly tied together: first, by means of the tie-beam, which rests on corbels fixed on the lower portion of the wall, which is thicker than the upper. The principal weight of the roof is carried down to this by means of the struts, *h h*, and to these the ties, *o o*, are attached, whilst the cross-pieces act as hammer-beams, being attached at their one end to the struts, and at the other to the end of the principals. The principals cannot thus spread outward, and as the hammer-beams, *i*, rest on the wall-plate *k*, on the upper edge of the wall, a second tie is secured. The principals are further confined at the top by a collar-beam, *m*, suspended from the king-post, *l*. The tie-beam is supported on bridging-joists, which run parallel to the *length* of the building, and are supported on posts, *d d*, the bearing of which is increased by the cross-pieces, *f*, shown in Fig. 160, which is a portion of a longitudinal section, in which will also be seen the method of giving additional support to the ridge-beam by the struts *n*, *n*.

The floor-joists are shown at *a a* and the purlins at *p* in both sections.

Fig. 161 shows the method in which the ridge-tree is attached to the head of the king-post; and Fig. 162 shows the joggle by which the ends of the principals are inserted.

Fig. 163 is a portion of a truss of a similar character drawn to a larger scale. As the trusses must necessarily be several feet apart, the purlins, which are, of course, of a smaller scantling, would be liable to sag. In Fig. 164, therefore, is shown the method adopted for giving support to their ends. This

The longitudinal section (Fig. 160) should be *projected* from Fig. 159 by drawing horizontal lines from the edges of the various members shown in the transverse section.

Fig. 166 is the section of a roof in which, although the tie-beam rests on the top of the walls, still the weight is carried downward to a much lower point. This is effected by means of perpendiculars, *a* (see enlarged view, Fig. 167), and struts, *e*, which being double, clasp the tie-beam, *b*, between them, as

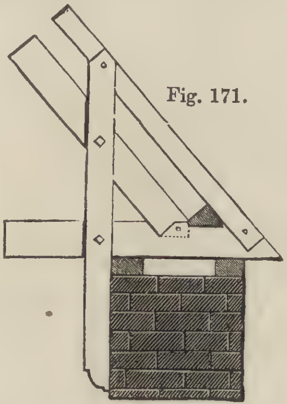


Fig. 171.

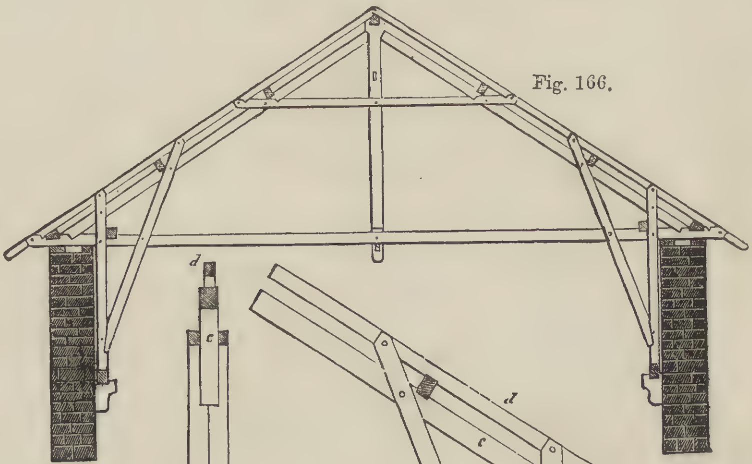


Fig. 166.

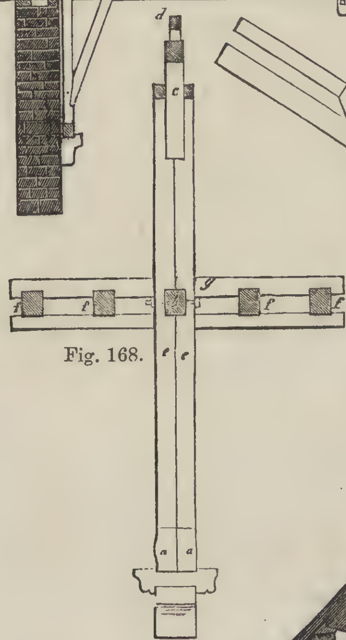


Fig. 168.

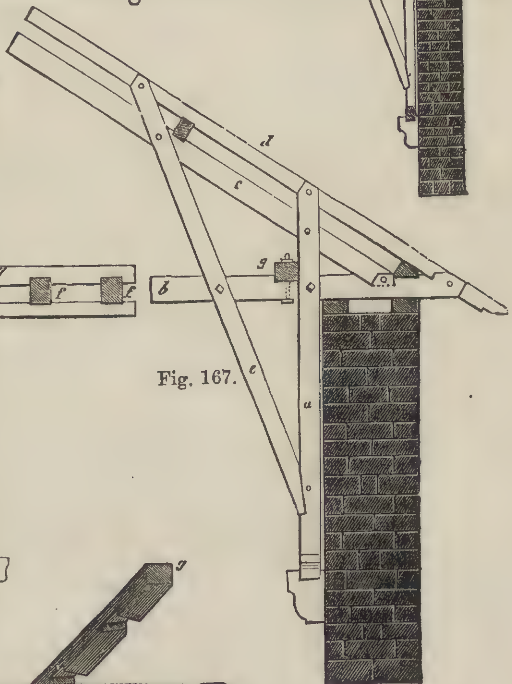


Fig. 167.

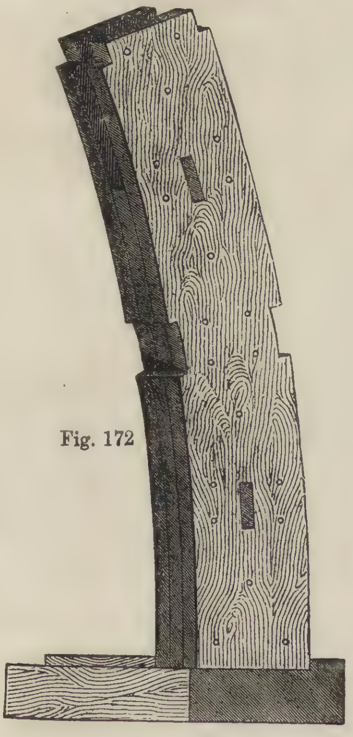


Fig. 172

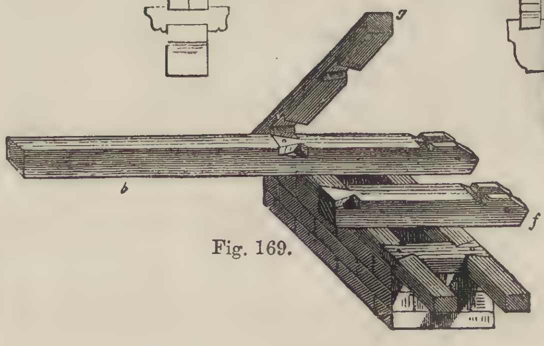


Fig. 169.

method consists in the placing of additional end-pieces. First, a longitudinal beam, *h*, is fixed at right angles to *g*, and therefore parallel to the wall-plate. The end-pieces are precisely similar in character to the end of *g*, and are inserted into *h* by means of a tusk-tenon wedged in. This is shown in a separate example in Fig. 165.

As to the mode of drawing this example, the walls should, of course, be drawn first, then perpendiculars for centre-lines for the supporting columns, then the corbels and tie-beam.

It will now be found convenient to draw the section of the wall-plates, the lower line of the principal rafters, the struts *h*, the hammer-beams, the king-post, collar-beam, floor-joists, and then to complete the columns and draw the purlins, etc.

shown in the enlarged section (Fig. 168), and carry the weight, not only of the principals, *c*, but of the common rafters, *d* (to which it will be seen they are also attached), down to a stone corbel built into the wall; the king-post being also made double, clasps around both tie-beam and collar-beam, and the mutual support thus given admits of timber of smaller scantling, and consequently of less weight, being used. Fig. 169 shows how the double wall-plates are connected by cross-pieces dovetailed into them. The sketch also shows the intermediate end-pieces, *f*, and the manner in which they are secured by the longitudinal beam *g*. Fig. 170 is the elevation of the end of a truss of a similar character, and Fig. 171 is the upper end of a strut clasped by a collar-beam inserted into a principal.

The De Lorme system of building up arched ribs has been alluded to in "Technical Drawing."—IX. (Vol. I., page 135), and it will be remembered that this consists in uniting timbers placed on their edges; these timbers being in short lengths, each cut out of the flat, so as to form a portion of the required curve, the different lengths being united by what is called the "break-joint."

This system has been used more or less ever since its invention. The roof of the middle compartment of the building formerly known as the Pantheon, Oxford Street, London, is constructed on this principle; but owing to the strength of the beams being so much dependent on the lateral cohesion of the fibre, the system has not been generally adopted in roofs, but has on the Continent been used in several large domes. The arch-beams of the original dome of the Halle au Blé, at Paris, built by Messrs. Legrand and Molino, was of this character, but this having been destroyed by fire, has been replaced by an iron one. The span of the original dome at its base was 120 feet. The largest dome in Germany constructed on the De Lorme principle is that of the Catholic Church at Darmstadt, a portion of one of the arch-beams of which is given in Fig. 172. These arched beams, however, do not continuously span the entire well —the diameter of which is thirty-three and a-half metres—but abut at the top against a ring, which is the base of the lantern, or skylight.

The ribs are not all carried up the whole height, but are alternated by narrower ones, which reach about two-thirds of the length of the others, the main ribs being constructed of five thicknesses of timber at their lower half, and of three above the middle—the intermediate ribs consisting of three thicknesses only.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XIII.—JAMES WATT.

BY JAMES GRANT.

JAMES WATT, the celebrated natural philosopher and civil engineer, the narrative of whose life is, in fact, the progressive history of the steam-engine, that most wonderful of all modern inventions, was born in Greenock, on the Firth of Clyde, on the 19th of January, 1736. His great-grandfather, an Aberdeenshire farmer, was killed in battle under the Marquis of Montrose, when fighting for King Charles I. The family from that time became poor, though James, the father of the engineer, rose eventually to be a merchant and magistrate in Greenock, where he died, at the age of eighty-four, in 1782.

James Watt, the oldest and only surviving child (his elder brother John having perished at sea), received his first instructions in reading from his mother, whose name was Agnes Muirhead; but he was taught reading and writing by his father. He was afterwards placed at the elementary public school of Greenock; but the delicacy of his health prevented a regular attendance at classes, hence the greater portion of his time he had to devote himself to unaided study in his own room. His love of mechanics was shown in his youth early, and even as a boy he began to consider with interest and thought the mighty power of steam, as the following perhaps somewhat hackneyed anecdote may serve to show:—

He was seated one evening at the tea-table of his aunt, Mrs. Muirhead. After silently observing him for some time, she said, "James, I never saw sae idle a bairn. Take a book, and employ yourself usefully. For the last half hour you have not spoken a word, and have done nothing but take the lid off that kettle and put it on again, or hold a silver spoon over the steam, watching it rising from the spout, and then counting the drops of water."

It would seem that while thus reproved for apparent idleness, the mind of the future engineer was thoughtfully considering the fact of condensation of steam. Every branch of science, as he approached manhood, he prosecuted with equal success; and, among others, took such interest in physic and surgery that he was one day discovered—to the intense dismay of his mother—conveying secretly into his room the head of a child, which had died of some unknown ailment, that he might dissect it.

A growing desire for improvement in mechanics induced him, in his nineteenth year, to visit London, where he placed himself under the care of Mr. John Morgan, a nautical and mathematical instrument-maker, whose premises were in Finch Lane, Cornhill; but in 1756 ill health compelled him to return home. His London experience, brief though it was, enabled him to pursue his studies without more instruction; hence in the following year he started in business at Glasgow as a maker of mathematical instruments. Some of the city trade corporations now attacked him legally, on the plea that he was infringing their privileges; but the professors of the University were so pleased with his skill and application that the Senatus took him under their protection, and assigned him apartments within their ancient college, where he could work unquestioned, as mathematical instrument-maker to that body. Those who most actively befriended him on this occasion were Dr. Dick, Professor of Natural Philosophy; Robert Simson, M.D., Professor of Mathematics; Dr. Black, Professor of Anatomy, the discoverer of latent heat; and Adam Smith, the author of "The Wealth of Nations," then Professor of Logic. For six years James Watt resided in the University, and during that time his shop became the daily resort of the most eminent men in Glasgow; and there many of the most difficult questions in literature, art, and science were discussed, to the advantage of all.

It is recorded as a proof of Watt's singular ingenuity that, though destitute of all ear for music, and unable to distinguish one note from another, he undertook to construct an organ, and actually built one, which displayed many improvements in mechanical details, "in the regulators and mode of measuring the force of the wind, and one, too, which showed no deficiency in its powers of harmony."

In the year 1764 he married his maternal cousin, Miss Miller, having in the summer of the year previous removed from the University into the city; and from thenceforward, aiming at a more ambitious career, he began to turn much of his attention to the improvement of the steam-engine.

In 1761 and the year following he had already tried some experiments on the power or force of steam in a Papin's digester, and had worked with strong steam a little model engine of his own construction; but its many imperfections prevented him at the time from proceeding with it further. It chanced that in the autumn of 1763, Professor John Anderson, who then held the chair of natural philosophy (the future founder of the famous Andersonian Institution), employed Watt to put in order a working model of a steam-engine upon Newcomen's construction, with which he was wont to instruct the students of his class.

At that time the usual practice was to condense the steam in the same cylinder as that in which the piston worked; but this cylinder, being of cast metal, was at every stroke cooled down nearly to the temperature of the water employed for condensation of the steam, hence causing the waste of all the heat requisite for giving the cylinder again its necessary temperature. After many experiments or trials, the happy idea occurred to Watt of saving all the waste of heat and fuel by condensing the steam in a separate vessel, exhausted of air, and kept cool by injection; while between it and the cylinder a communication was to be opened each time the steam was to be condensed, while the cylinder itself was to be kept perpetually hot. On perfecting this great improvement he constructed an entire model, and the success of the experiments made with it placed the advantages of the invention beyond all doubt.

This model has ever since been preserved in the University of Glasgow. In the course of his trials with it, he ascertained to a nicety the exact proportions between water and steam, and also the quantity of water which the heat disengaged by condensing steam would elevate to the boiling-point. On Watt mentioning this discovery to his friend Dr. Black, the latter explained to him his doctrine of latent heat, to the support of which Watt had the pleasure in future years of contributing his experiments.

Want of funds for a time prevented him from continuing his machinery upon a larger scale, but for two years after the discovery his mind was occupied almost exclusively by this desire. However, about 1768, Dr. John Roebuck, of Sheffield, famous as an experimental chemist and metallurgist, and as the improver of the blowing apparatus, having commenced his great establishment of the Carron Iron Works, agreed to speculate with Watt upon being admitted to two-thirds of the invention. Prior to this proposal Watt had been fast losing heart. We are told that he "was a sickly, fragile man, and a constant

sufferer from violent headaches; besides, he was by nature timid, desponding, painfully anxious, and easily cast down by failure. Indeed, he was more than once on the point of abandoning his invention in despair."

Aided by Roebuck, he now constructed an engine on a large scale at Kinneil, near Borrowstownness; but pecuniary difficulties on the part of the doctor and increasing engagements on the part of Watt delayed for a time the progress of the work. The latter had now entirely relinquished the business of mathematical instrument-maker, and commenced that of civil engineer. In 1767 he was employed on a survey for a junction canal between the Forth and Clyde, by what was called the Lomond passage, but the bill was lost in Parliament. His next survey was for the Monkland Canal, which was commenced in 1770, and has undergone many improvements since 1792. It is twelve miles long, thirty-five feet wide at the top, and twenty-six at the bottom, with six feet of water.

Many plans of a similar nature occupied his attention till 1773, and surveys and estimates were made by him successively for improvements in the harbours of Ayr, Port Glasgow, and Greenock; for the deepening of the Clyde, improving the navigation of the Forth and Devon; the cutting of a canal from Campbelltown to Machrihanish Bay; of another between the Grand Canal and the harbour of Borrowstownness; the erection of a bridge at Rutherglen, in 1775, another at Hamilton, etc. He surveyed the district of the Caledonian Canal, with plans and sections, which proved of vast use to Mr. Telford, when at a future time that great engineer carried out the works upon a larger scale. To facilitate those surveys, Watt used a new micrometer and a machine for perspective drawing, invented specially by himself.

The year 1769 saw him fully secured by patent in his "improvement for saving steam and fuel in steam-engines;" and having prevailed upon Dr. Roebuck, now by luckless speculations involved in ruin and penury, to transfer all his interest in the said patent to Matthew Boulton, of Soho, in Staffordshire (a village of which that gentleman was the founder), Watt entered into partnership with him, and removed to Birmingham about 1774, a year after the death of his first wife, who left him a son and a daughter. As success in life flowed in upon him he never forgot his gratitude to Dr. Roebuck. "I have met with many disappointments," he once wrote to a friend, "and I must have sunk under the burden of them if I had not been supported by the friendship of Dr. Roebuck."

The patent having been extended to twenty-five years, Messrs. Watt and Boulton now commenced actively at Soho the construction of engines for the drainage of mines, then the chief purpose to which they were applied. These engines speedily came into general use in the mining districts, more especially, perhaps, in Cornwall; and Watt now proceeded to invent still further improvements, all of which he secured by successive patents between the years 1781 and 1785. Among other discoveries were the rotatory motion of the sun and planet wheels, the expansive principle, the double engine, the parallel motion, and the smokeless furnace. The application of the centrifugal regulating force of "the governor" was one of his principal practical improvements; while the perfection to which he brought the rotative engine soon led to its application to every species of mill-work and machinery. But Boulton and Watt were frequently compelled to have recourse to law between the years 1792 and 1799, as several piracies were committed on the rights of their patent.

By this time Watt had re-married, his second wife being a Miss Macgregor, the daughter of an old Glasgow friend.

In 1780 he had obtained a patent for a letter-copying machine, specially his own invention; and in April, 1783, he announced his important discovery of the composition of water, which M. Arago styled "the greatest and most prolific discovery in modern chemistry." His paper on this subject was read before the Royal Society of London, and published in their "Transactions," in 1784. In the following year he was elected Fellow of the Royal Society of Edinburgh, and in 1786 a fellow of that of London.

The winter of that year found him at Marly, whither he had gone at the request of the Government of Louis XVI., to improve the mode of raising water in the famous royal gardens there. It was on this occasion that he won the friendship of M. Berthollet, the eminent chemist, who had recently discovered the bleaching qualities of chlorine. These he communicated to Watt, and the latter, on receiving permission, imparted them to his father-in-law, Macgregor, who was then proprietor of a great bleaching establishment near Glasgow. For this place Watt gave directions concerning the construction of the proper machinery and vessels, superintending the first trials; so he was thus virtually the first to introduce this improvement into Britain.

The year 1800 saw the expiration of his patent, after which he withdrew from the works at Soho in possession of an ample fortune, the just reward of his skill, perseverance, and industry. To his two sons—the youngest of whom, Gregory Watt, had already distinguished himself by literary and scientific talents—he resigned all his interest in the business; but still in retirement devoted a great portion of his time to chemical science, and contributed a paper on the medical qualities of factitious airs to Dr. Beddoes' treatise on "Pneumatic Medicine." He received the degree of LL.D. from the University of Glasgow, in 1806; and eight years after he was elected one of the eight foreign associates of the National Institute of France.

In 1809 his aid was solicited by the Glasgow Water Company to enable them to convey water across the Clyde from a well on the opposite side of the river. For this purpose he formed a flexible main, with ball-and-socket joints, to be laid across the bottom of the water, an idea he derived from observing the structure of a lobster's tail, and in its design and execution the success of the plan was complete. His advice was next asked concerning the formation by Government of new docks at Sheerness, and for his services in this matter he was thanked in 1811 by the Lords of the Admiralty.

In the last year of his long and useful life, Watt was engaged in the construction of a machine for copying pieces of sculpture. He did not live to perfect this clever instrument, for his hands and sight were failing him; but it was so far advanced that he had several models made and given to his friends, as "the attempts of a young artist, just entering his eighty-third year!"

"In his private life James Watt was universally beloved for his genius, esteemed for his benevolence, and courted for the vast range of his information. His conversation was pleasing, abounding with anecdote, and highly instructive. He had read much, and was familiar with several languages. The German he learnt solely that he might peruse Leopold's 'Theatrum Machinarum' in the original."

Among the many inventions of Watt was a tilt-hammer of considerable power. This he first worked by means of a water-wheel, and latterly with a steam-engine regulated by a fly-wheel. His first hammer weighed 120 pounds, and rose eight inches before striking; but he afterwards made one for Mr. Wilkinson, of Bradley Forge, which weighed 7½ cwt., and struck 300 blows a minute. In common with Wedgwood and Sir Humphry Davy, the idea of sun-painting by the daguerreotype had occurred to Watt, who had experimented on the action of light upon nitrate of silver; and very recently, among the old household lumber of his partner, Matthew Boulton, there was found a silvered copper-plate, having on it a representation of their old premises at Soho.

On the 25th of August, 1819, he died, in his eighty-third year, at his house at Heathfield, in Staffordshire, and was interred in the chancel of the parish church of Handsworth, near Birmingham, where a beautiful Gothic monument, with a marble statue by Chantrey, has been erected to his memory. Another marble statue of Watt by the same artist decorates one of the halls of Glasgow University; a third stands in his native town of Greenock; a fourth, of bronze, is in one of the principal squares of Glasgow; a fifth, of stone, is in Edinburgh; and in Westminster Abbey there stands a sixth, of colossal magnitude, by Chantrey, bearing on its base an elegant inscription from the pen of Lord Brougham.

A relic of Watt's skill and industry still exists in his large steam-engine at Carron. It remains in its old position, but is hastening fast to decay. Already the engine-room is crumbling into ruins, and the iron-work is furrowed and blackened by oxidation, as it was abandoned when one of a more improved design was erected about 1840. But as Watt's engine is one of the earliest ever made, and is, as a piece of mechanism, most interesting to men of science, it is much to be regretted that so little care is taken for its preservation.

TECHNICAL DRAWING.—XXXV.

WHITWORTH'S 15-INCH LATHE—(*continued*).

Fig. 347.—The movable headstock and part of bed.

Fig. 348.—An end elevation of the fixed headstock, referred to in the last lesson.

WROUGHT-IRON BOX-GIRDER.

Fig. 349 shows a side elevation and Fig. 350 a section of a girder, such as used for supporting walls for buildings. It consists chiefly of four plates and pieces of angle iron, that are riveted together, forming a very strong box-shaped girder or beam. The plates are cut into proper form by shears, in a shearing and punching machine, and holes are punched for the rivets. In their original form rivets have one head, and when red-hot are put into the holes that have been punched. A heavy piece of iron, technically called a "dolly," is held against the head, while the projecting end is hammered over, and by means of a die made into another head. As the rivet cools, it contracts, and so draws the plates very closely together.

This plan is universally adopted for fastening together the plates for boilers, wrought-iron bridges, roofs, etc., and has the merit of extreme simplicity, combined with durability and strength.

VERTICAL STEAM-ENGINE WITH CYLINDER INVERTED (Fig. 351).

In cases where ground-space is valuable this form of the steam-engine is sometimes employed, as it takes up less room than that occupied by the horizontal or beam engine; but it is used most frequently for marine purposes. The cylinder, A, is above, and steam pressure upon the piston inside it produces a reciprocating motion, which, by means of the connecting-rod, B, is communicated to a crank, C, below, and thereby converted into rotation. At the point shown the crank is on the top of its stroke, and as pressure now acts in a straight line between the piston and shaft, D, no motion can take place until the crank has moved sideways a little. When once past this point (called the *dead centre*) the engine-shaft will turn round, and the momentum of the fly-wheel, E, prevents its ever standing fast upon the dead centres. Another plan, recently invented by Mr. A. Rigg of Chester, and Mr. W. Macgeorge of London, for accomplishing this object, is shown in the lower part of the drawing. It consists of a cam, F, keyed upon the main shaft, D, and a roller, G, carried in bearings upon a plunger, H, which has steam pressing underneath it. As shown in the drawing, the steam forces up the plunger and roller, and so turns round the cam, and with it the main shaft and crank. This plan differs from the fly-wheel, inasmuch as it is a real power, which turns the engine round and starts it even if standing (as shown in the drawing), which could never be done by the fly-wheel. It is also much lighter than a fly-wheel, therefore more suitable for ships; and indeed it answers the purpose of a second engine with a crank set at right angles to the one shown. Although both a fly-wheel and cam arrangement are shown in the drawing, only one of them is really necessary, and this drawing forms an example of alternative designs, where two separate or distinct arrangements may be proposed by the designer. In these cases it is usual to make one drawing with ink of a different colour, such as showing the fly-wheel in crimson lake or Prussian blue.

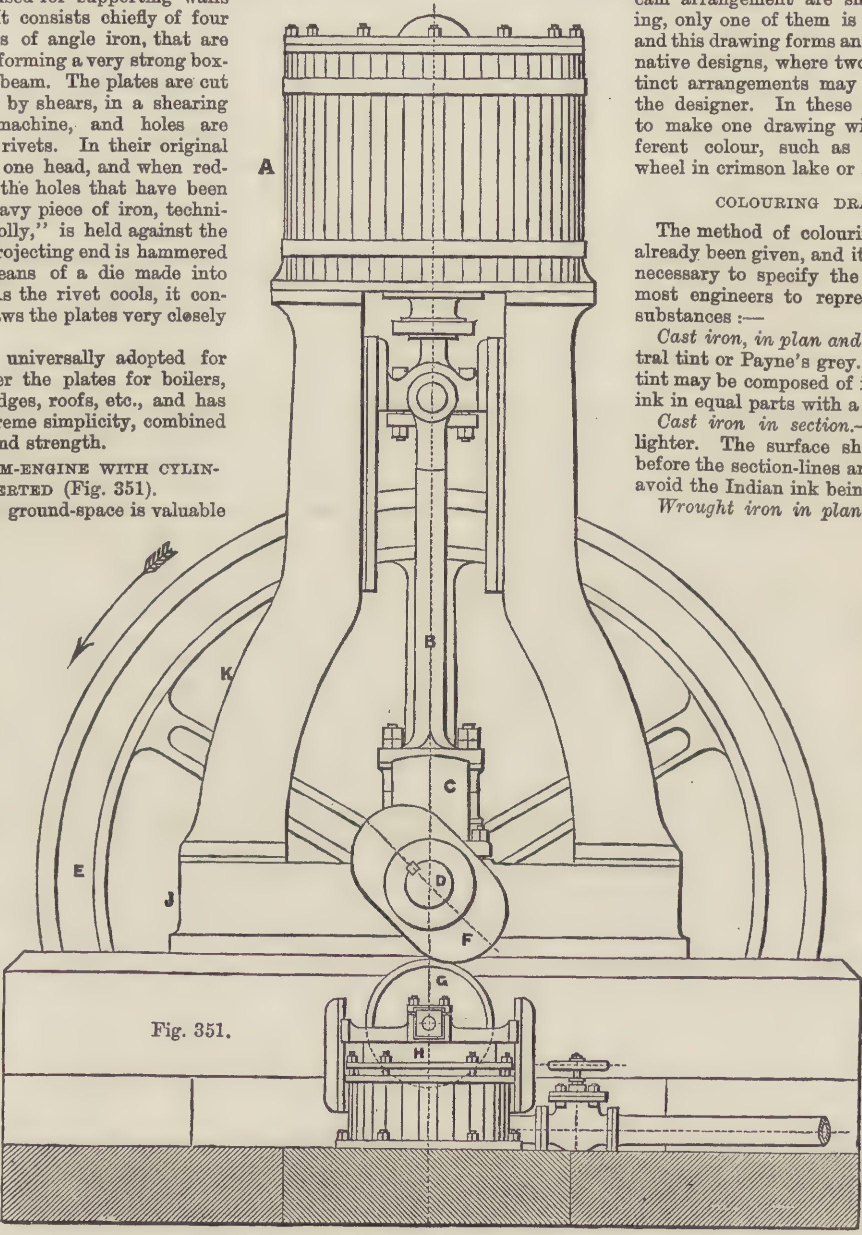


Fig. 351.

COLOURING DRAWINGS.

The method of colouring drawings has already been given, and it is only therefore necessary to specify the colours used by most engineers to represent the various substances :—

Cast iron, in plan and elevation.—Neutral tint or Payne's grey. A good neutral tint may be composed of indigo and Indian ink in equal parts with a little lake.

Cast iron in section.—The same used lighter. The surface should be coloured before the section-lines are drawn on it, to avoid the Indian ink being washed up.

Wrought iron in plan and elevation.—Indigo.

Wrought iron in section. — The same, lighter, with section-lines.

Steel. — Pale indigo tinged with lake.

Brass.—Gamboge, or, Roman ochre, shaded with sepia, which should be done *before* the gamboge is applied.

Copper. — Lake.

Lead. — Pale indigo tinged with Indian ink.

Brickwork in plans and sections.—Lake.

Brickwork in elevations.—Lake mixed with burnt sienna or Venetian red.

Oak or Teak. —Vandyke brown.

Lighter woods—such as fir.—Raw sienna.

Granite.—Pale Indian ink.

Stone generally.—Yellow ochre or pale sepia.

Leather.—Vandyke brown.

Concrete works.—Sepia with darker markings.

Clay or Earth.—Burnt umber or Vandyke brown.

Slate.—Indigo and lake.

In colouring drawings the student should always bear in mind that if any depth of tint is desired, it can only be attained by laying on a succession of washes until the desired tint has been produced.

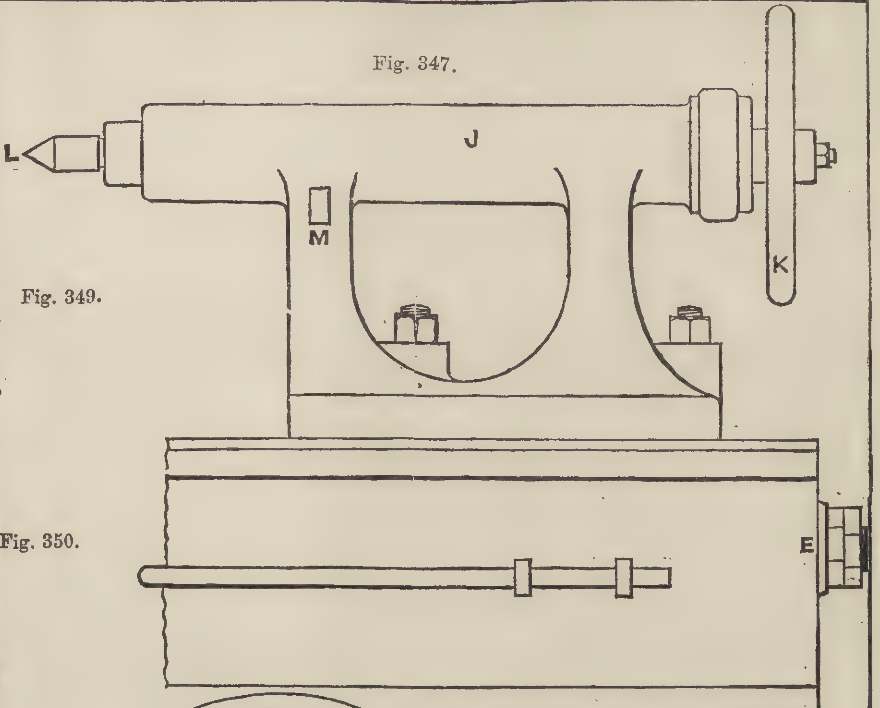


Fig. 347.

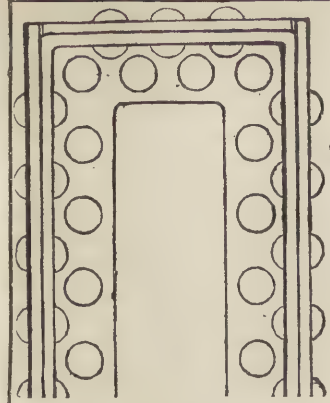


Fig. 349.

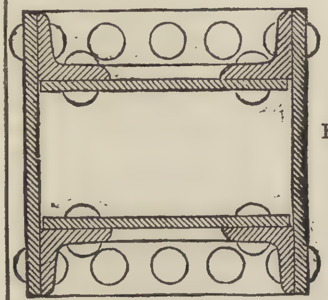


Fig. 350.

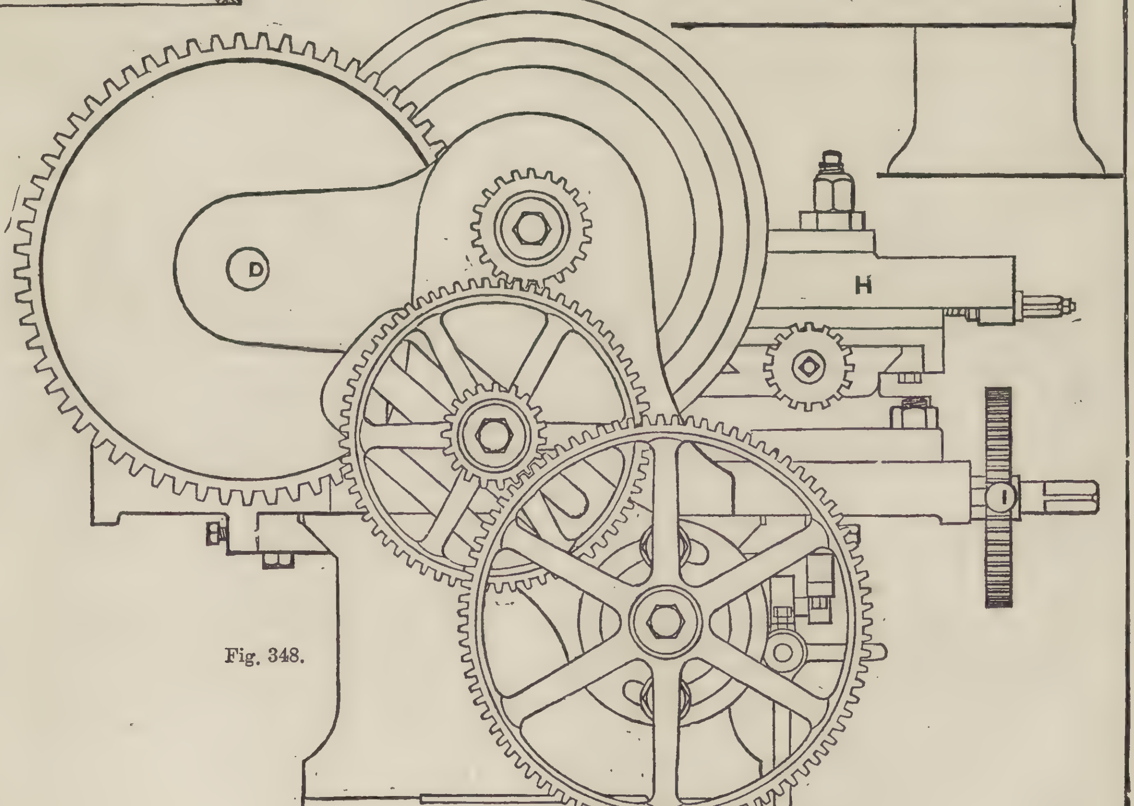


Fig. 348.

NOTABLE INVENTIONS AND INVENTORS.

XIV.—THE SILK MANUFACTURE AND JOHN LOMBE.

BY JOHN TIMBS.

It is a curious fact that all those animals which are most useful to man are likewise most manageable. There is scarcely a caterpillar which is so easily reared as that of the silkworm.

China was, undoubtedly, the country in which men first availed themselves of the labours of the silkworm. Seria (the country of the Seres, whence the rearing of silkworms is called *sericulture*) was a name by which the Macedonian Greeks designated the country which produced the silk that came overland from the north of China. Still, there are reasons for inferring that the culture of the silkworm and the manufacture of silk had not been introduced into India four hundred years after silk was known in Europe. Both the raw material and the manufactured article were obtained in the country of the Thinæ. The Median robes spoken of by the Greek writers of the period of the Persian empire, and extolled for their lustrous beauty and brilliancy, were no doubt silken vestments, and long afterwards, when they had been introduced into Europe, they were called silken. Aristotle is the first Greek author that mentions the silkworm; and he states that the silk was first spun in the island of Cos, but the raw material was still an Oriental product. Pliny states that the silk came from Assyria, and was worked up by the Greek women.* It is probable that silk was in use among the Greeks long before they knew whence the substance came, or in what manner it was produced. Virgil supposed that the Seres carded the silk from leaves; and Dionysius Periegetes also supposed it to be a vegetable product. Thus, he says:—

> "Nor flocks nor herds the distant Seres tend;
> But from the flow'rs that in the desert bloom,
> Tinctur'd with varying hues, they cull
> The glossy down, and card it for the loom."

Pausanias says: "The Seres have a spinning insect, which is kept in buildings, and produces a fine-spun thread, which is wrapped about its feet." It was not until the sixth century that the obscurity which enveloped the subject was cleared up. At this time silk was in general use among the Romans, and was manufactured for them by the inhabitants of Tyre and Berytus, in Phœnicia. The Persians monopolised the supply of the raw material, and guarded their trade both by sea and land, so that travellers from or to China were not allowed to traverse the Persian dominions; and in the time of Justinian the importation of silk was entirely stopped. The trade in silk was in this unsatisfactory state when two Nestorian monks of Persia, who had travelled to China, there saw the common silken dress of the Chinese, and the myriads of silkworms on trees and in houses, from which it was obtained. On their return to the West they acquainted Justinian with the mode of producing silk, and undertook to return and bring back with them some of the eggs of the silkworm. This they did, and a quantity of eggs concealed in a hollow cane were brought in safety to Constantinople, and there hatched by the heat of a dunghill, and fed with mulberry-leaves. These worms in due time spun their silk, and propagated, under the careful attendance of the monks, who also instructed the Romans in the whole process of manufacturing silk.

The breeding of silkworms in Europe was for six centuries confined to the Greeks of the Lower Empire. In the twelfth century the art was transferred to Sicily; in the thirteenth century the rearing of silkworms and the manufacture of silk were introduced into Italy, and thence successively into Spain* and France; and in the fifteenth century the manufacture was established in England.

Of all fabrics, that which may be called most historical and of greatest interest to the artist and antiquary is, undoubtedly, silk. Though less early known and manufactured, its beauty is so great and its capacity for fine fabrics so obvious that it has become associated with the ceremonies, splendours, and events of all times—modern times, at least. This costly material, as we have seen, came late to the Romans. From that time it became *the* material for ceremonial dresses, religious and civil; and on all important occasions, down to the costly displays of modern coronations and great Church ceremonies, silk, in the form of tissues, velvets, satins, and the like, has been always in use. The early home of silk, however, has been in the East; and wonderful fabrics are still made in India and Syria with silk mixed with gold threads, beetles' wings, and other decorative substances.

It was not until the reign of Francis I. that the silk manufacture took root in France. At this date Henry VIII. could only obtain a pair of silk stockings from Spain; and the manufacture in England did not make much progress until 1585, when many of the silk manufacturers from Antwerp fled to England from the persecutions of the Duke of Parma, then governor of the Spanish Netherlands. James I. was very solicitous to promote the breeding and rearing of silkworms in England, and had great numbers of mulberry-trees planted for the purpose; the northern side of the site of Buckingham Palace was a portion of the mulberry garden planted by King James. The experiment was not successful, in consequence of our climate being unsuited to the silkworm. James also encouraged the introduction of the silkworm into the English settlements in America. Near the close of his reign, James encouraged a London merchant to bring from the continent of Europe silk-throwsters, silk-dyers, and broad-weavers; and a beginning was made in the manufacture of raw silk into broad silk fabrics, which increased so rapidly that in 1629 the Silk Throwsters of London were incorporated, and the trade had its dye called "London black." In 1661 this company employed above 40,000 men, women, and children. The revocation of the Edict of Nantes by Louis XIV., in 1685, compelled "poor Protestant strangers, Walloons and French," manufacturers and artificers, to emigrate from France in great numbers; when nearly 50,000 took refuge in England, and established such seats of silk manufacture as that of Spitalfields, of the highest style of art and ingenuity of fabric then known, introducing the weaving of lustrings, alamodes, brocades, satins, paduasoys, ducapes, and black velvets. And in 1713 it was stated that silks, gold and silver stuffs, and ribbons, were made here as good as those of French fabric, and that black silk for hoods and scarves was annually worth £300,000. Thus Louis XIV. sent thousands of the most industrious of his subjects into this country, to present his bitterest enemies with the arts and manufactures of his kingdom. Tapestries and hangings for rooms were manufactured in Spitalfields even before the settlement of refugees in that district. In the above year the petition of the Weavers' Company to Parliament, at the Peace of Utrecht, against the commercial treaty with France, represented the silk manufacture as twenty times greater in amount than it had been in 1664; and that it had caused a great exportation of woollen and other manufactured goods to Turkey and Italy, whence the raw silk had been imported.

In the early part of the eighteenth century the Italians exclusively possessed the art of spinning, or, as it is technically called, *throwing* silk; and the British weaver had to import thrown silk at an exorbitant price. In 1702 a Mr. Crotchet had attempted to establish the silk-throwing trade in a small

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* Pliny, whose judgment and discrimination as a compiler are not greatly to be relied upon, reports that the *bombyx* (or silkworm) is a native of Cos, an island in the Mediterranean archipelago. It is known that silk was manufactured there at a very early period; but Artistotle had previously explained that *bombykia*, or the stuff produced from the *bombyx*, was re-grown, or re-woven by the women of the above island. The inventress of this process was Pamphilia; she unwove the previous material to re-compose it in her loom into fabrics of a more extended texture; thus converting the substantial silks of the Seres into thin transparent gauzes, obtaining in measure what was lost in substance. Attempts have been made to rob the inventress of all the merit belonging to the process by identifying the *bombykia* with the raw material, which it is said Pamphilia and her nymphs procured from Seres, and thus spun or wove into *serica* or silk. But the fact of re-weaving rests upon too good authority to be doubted.—*Encyclopædia Britannica.*

* "The rich and beautiful brocades which adorn some of the Spanish royal palaces, and of which the colours are as fresh as if lately woven, were made many of them a hundred years ago, in Spanish looms. Looms and factories were broken up and demolished during the Peninsular War, and have never since been reconstructed or rebuilt. That war caused, in fact, the total annihilation of the silk trade in Spain—for the little woven in Valencia is scarce worthy of the name—and was the cause of much improvement in French manufacture."—*The Echo*, Jan. 7, 1871.

mill which he built at Derby; but from defects in his machinery he was soon compelled to abandon the project. In 1715, John Lombe, whose name will ever be remembered with veneration in connection with the silk trade, visited Italy to acquire a knowledge of its process, with the view of introducing it into England. On reaching Italy, he found the Italians guarded their secret with great vigilance. At Piedmont, finding that he could not examine the silk machinery and its processes, he bribed some of the workpeople; and, by their connivance, in the disguise of a common workman, he made several visits to the mills, and each time carefully noted down whatever he saw, and made sketches of parts of the machinery, so as to perfect himself in the operation of throwing. His stratagem was discovered, and he was obliged to fly with the utmost precipitancy, bringing with him, however, his notes, sketches, and portions of the machinery, and, better still, a mind which had grasped and comprehended the whole process. He fled to avoid assassination, and took refuge on board ship; and returned to England with a full knowledge of the art he had run such imminent risk to acquire. He was accompanied in his flight by two Italian workmen whom he had bribed, and who risked their lives in his project.

MINING AND QUARRYING.—V.

BY GEORGE GLADSTONE, F.C.S.

COAL.

VENTILATION — FIRE-DAMP — CHOKE-DAMP — DAVY LAMP — BLIND PITS — THE PIT'S MOUTH — SPONTANEOUS COMBUSTION.

WHEN there are two shafts to a colliery, the one nearest to the dip-head will be the downcast, and that towards the crop the upcast, as the air will naturally tend in that direction independently of any artificial arrangements. The air in the coal-mines is liable to be contaminated with two different gases, known by the miners as fire-damp and choke-damp, the former consisting of carburetted hydrogen, and the latter of carbonic acid. The fire-damp is much lighter than common air, and when mixed with it in the proportion of 1 of gas to 10 of air, it forms a highly explosive compound; the carbonic acid is, on the contrary, heavier than the air, and will extinguish fire, but in breathing it insensibility ensues, and ultimately death. The fire-damp, however, is the principal source of danger. Some seams are very full of it. In the low main of the Newcastle fields, for instance, a miner has been known to come upon a blower giving off 6,000 cubic feet of gas per minute, and these sometimes continue without diminution for months. The fire-damp will not explode if the air is in the proportion of 14 or more to 1 of gas, so that it becomes a matter of calculation as to the rate at which the fresh air should be made to circulate through the mine. It is not found convenient by the pitmen if the current of air exceeds three and a half feet per second, but in the main intake courses it may be increased to four or five feet per second, while owing to the expansion of the air with the increased temperature, and the escape of gases throughout the mine, the velocity in the return main will be very much greater.

In describing the underground plan of a mine a furnace at the bottom of the upcast shaft has been spoken of. It may, however, appear curious that a large fire should be kept burning in a coal mine at the very part towards which the explosive gases are driven. Furnaces at the top of the shaft, with a very tall chimney to increase the draught, have been suggested instead, but the other is more effective. In collieries where there is any reason to fear an excessive quantity of gas the return air-course is not allowed to pass immediately over the furnace, but is carried by a *dumb drift*, A, as shown in the diagram (Fig. 10) in the next page, into the upcast shaft, B, at some little distance above the furnace, the fire in which is fed with fresh air brought in by the air-course, C.

How effective the ventilation is may be judged from the following observations made at Shireoak Colliery, 1,530 feet deep. The temperature of the intake air at the bottom of the shaft was 63° Fahrenheit, and that of the return air 69°; while in a goaf twenty-one feet from the air-current the heat was 72°, and in a close heading 240 feet from the air-course it amounted to 86°. This last is considerably above what it should be, considering the depth of the colliery, but it exhibits the cooling effect of the air-current all the more conspicuously.

In Rosebridge Colliery, Wigan, where two seams are worked, the one 900 and the other 1,800 feet deep, the respective temperatures of the intake and return air at both levels were taken on the 4th of September, 1860, together with the strength of the air-currents and the length of course travelled by them. The temperature of the air in the shade at the surface was on that day 56°, which is above the mean of the year in this climate. That of the intake air at the bottom of the shaft in the upper level was $59\frac{1}{2}$°, and in the lower level $60\frac{1}{2}$°; after traversing 1,000 yards in the former and 1,500 yards in the latter the temperatures were 64° and 73°, the supply of air to the two levels being respectively at the rate of 35 and $81\frac{3}{4}$ cubic feet per minute. According to our previous estimate, the temperature of the lower level, due to the depth, should be about 81°, showing a reduction caused by the draught of 8°, although, on this occasion, the fresh air poured in was itself comparatively warm. This reduction of the temperature by ventilation has, by the way, been taken into consideration in fixing the limit of coal-mining at about 4,000 feet.

The length of the air-courses in some of the old collieries in the north of England is enormous—even thirty or forty miles—so that the air introduced from above will perhaps be ten or twelve hours before it makes its exit.

In order to diminish as much as possible the risk of explosions, the lamp invented by Sir Humphry Davy, and which bears his name, is very commonly adopted, though not to the extent it ought to be, as the pitmen use naked candles wherever possible, because they give more light. It was found by experiment that fine iron gauze will not allow fire to pass through. The Davy lamp, of which Fig. 11 is a drawing, is therefore made quite air-tight below, while the sides and top are made of a sheet of iron gauze, through which the air required for combustion passes. The oil lamp in the centre is trimmed and lighted before starting, and the gauze cylinder screwed down tight. A is the receptacle for the oil, which is poured in at B, upon which a close-fitting cap is then screwed. C is a metal rod with a claw at the inner end, passing through the oil chamber by an air-tight pipe into the lamp, which is used for trimming the wick, when in the mine, without unscrewing the gauze cover. A gauze containing twenty wires per linear inch will be sufficiently fine for the purpose, though they have often been made much closer. On passing into a gallery where fire-damp prevails, the gas, passing through the meshes of the gauze, will make the lamp burn with increased brilliance; and if the gas is present in any quantity the whole inner surface of the gauze will be covered with a pale blue flame, but it will not communicate with the outside. If the fire-damp should be so abundant as to constitute a third of the volume of the air, it is no longer combustible, and the lamp will go out altogether. This will tell the miner that the atmosphere is no longer fit to breathe. Notwithstanding all precautions, however, the number of accidents is still very large; in 1868 the fatal cases in coal-mines arising from all causes amounted to no less than 1,011, being nearly three for every 1,000 men employed.

Some machines have been invented for cutting the coal, and in the face of such statistics it will be admitted that every appliance which will reduce the manual labour should be hailed as a boon. A variety of patents have been taken out for this purpose, and in some mines they have been successfully used.

When the coal is *got*—that is, broken down from the seam—it is put into baskets or trucks, and conveyed to the main galleries, which are usually laid with trams, and where ponies are frequently employed in drawing the trains of laden trucks to the pit bottom. Unlike the pitmen, who always return to their houses above ground as soon as their day's work is done, these ponies live below, stables being built for them near the bottom of the downcast shaft, so as to afford them as much fresh air as possible.

At the bottom of the shaft the coal is transferred to the square tubs, which are made to fit the shaft and run in grooves; when a signal is given to the engineman above, they are rapidly drawn to the surface. The pitmen ascend and descend in the same tubs, but when any of these are coming up, a different signal is given. Iron wire rope is now generally used for hauling, though in some cases flat hempen ropes are employed. The rope is generally wound round a large drum, and is often so

arranged that one operation of the engine raises the tub in one segment of the shaft, and lowers the empty one at the same time in the other. By a dial and self-registering apparatus the engineman can tell exactly when the tubs have reached the desired level, a point which it is important he should know when two or more seams are worked from the same shaft.

If the seam, or any part of it, should have a considerable dip, an inclined plane worked by a windlass is substituted for ponies in the main galleries.

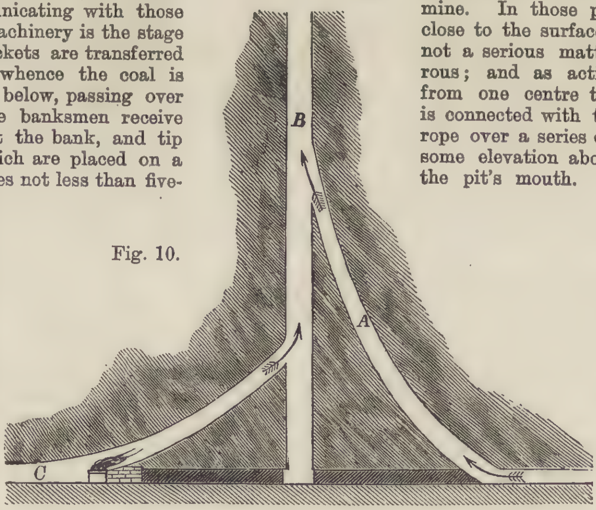
More than one seam of coal is often worked from the same shaft. In doing this the distance between them, and the strength of the intervening rock, have to be considered. If a lower seam is worked first, the extent of the operations should be limited so as not to disturb the overlying beds; and where there is any risk of this the upper seams ought to be exhausted first. A mine may, however, be well opened up, leaving large pillars to support the roof while the upper seam is being worked out. For this purpose *blind pits* are very often constructed. They are small shafts, sunk at any convenient part of the workings from one level to another, without being carried up to the surface.

The principal shaft cannot always be sunk at the dip, as there might be a village, or a river, or even the sea in the way. In such cases the drainage water and also the coal as it is wrought will have to be brought uphill to the pit bottom. If the under dip workings are to be carried to any considerable extent, a small high-pressure engine is generally erected at the bottom of the shaft, which pumps the water up to that level, and also draws up the loaded trucks to the same point.

We must now return to the surface. The pitmen, when their day's work is over (the work proceeding night and day by relays of men), are rapidly drawn up in the empty coal buckets, which at other times would be filled with coal. Here, at the pit's mouth, is a large establishment—the pumping-engine, which, in a mine that has been extensively opened out, will be kept going constantly; and the winding-engine, connected with the large drum round which the iron-wire rope is coiled, and which is the sole means of communicating with those below. In addition to this machinery is the stage or bank, to which the coal buckets are transferred on arriving at the top, and whence the coal is emptied out into the wagons below, passing over the screens on its way. The banksmen receive the tubs on their arriving at the bank, and tip them up over the screens, which are placed on a slope, having transverse meshes not less than five-eighths of an inch wide, all that passes over such a screen being ranked as large coal. In separating the small from the nuts, screens of three-eighths mesh are used. A line of railway runs just below the lower end of the screens, and the empty wagons are so placed that the large coal passes into them at once. When a sufficient number of wagons are filled, they are sent off to the main line of railway or port of shipment. At the screens boys are employed to watch for any brasses or pieces of slate, which they pick out and throw on one side, such being injurious to the commercial value of the coal. In the large collieries of the north of England the shipping arrangements at the sea-port form a part of the establishment. On arriving at the wharf or staith the bolts which secure the bottoms of the coal-wagons are drawn, and the contents pass through and down a shoot into the ship or barge which lies floating below.

Fig. 11.

Fig. 10.



The director-in-chief of the mining operations is called a viewer, who has his house and offices near the pit's mouth; the under-viewers have to see that all is going on properly below. The fitter has under his charge the shipment and sale of the coals.

Even when the coal is shipped the risk of explosions is not altogether over. The time being frequently very short between the working of the coal and its being put on board ship, the gas in the lumps of coal has not had time to escape, and if the hatches of the vessel are closed down as soon as the coal is on board, the gas given off, being much lighter than air, will collect immediately under the deck, and find its way out through some little chink between the boards. If this should happen to lead into the cabin, a person going in after nightfall with a naked light would probably be the sufferer by an explosion of sufficient force to blow up all the deck of the vessel. In some ports regulations are made prohibiting the closing of the hatchways for a certain number of hours, in order to allow of the free escape of the gas. There need be no fear of such a disaster after the first day.

Coal is, however, liable to spontaneous combustion. This is generally occasioned by the presence of pyrites or sulphide of iron, which decomposes with the action of the air, and in decomposing a great deal of heat is evolved, sufficient often to set the coal on fire. Coal containing a good deal of small, especially if it be rather wet, is the most liable to this risk. If such a result is feared, the best thing to be done is to turn it over and spread it out as much as possible, so as to let the heat diffuse into the air.

In the foregoing descriptions we have, for the sake of avoiding confusion, taken as our model one of the large collieries such as are to be found in the Newcastle coal-field, except where special mention has been made to the contrary. Coal-mines, however, vary greatly in different parts of the country; many of them are very small, and the whole arrangement of them much simpler. In short, there is every grade, from the open working near Dudley, to the deep and elaborately organised mine. In those parts where the coal seams lie close to the surface, and the sinking of a shaft is not a serious matter, the shafts are very numerous; and as active operations are transferred from one centre to another, the hauling-engine is connected with the new shaft by carrying the rope over a series of wheels, fixed at intervals at some elevation above the ground until it reaches the pit's mouth. In such districts as these, when a fault is reached the work in that pit would be terminated, and a fresh one commenced on the other side of the fault; whereas in a deep mine, if the throw is not very great, a drift would be made through the rock on an incline, and if necessary a blind pit made until the seam is cut on the further side of the fault, when the workings would continue to be carried on from the same centre as before.

Occasionally the seams are tilted up so very much that the pitman stands upon the coal, and has the roof and floor of the bed as walls on the right and left. The shaft is then generally sunk in the seam, and the coal is worked out by running galleries at different levels along the course of the seam. Some interesting specimens of this mode of working occur in the neighbourhood of Edinburgh, where the position of the beds is very much disturbed.

PRACTICAL APPLICATION OF THE FINE ARTS.—II.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

DESIGN.

Pursuing the plan that we have laid out, we will first describe the style of designs suited for a painted window—not that the man beginning, without previous experience in the art, to paint glass will usually be troubled in his early attempts about a design; if he be wise, he will take some design ready to his hand, either suggested by a bit of old glass or copied from a drawing in some of the numerous works which give specimens of work, both ancient and modern, already in existence. Nevertheless, it is advisable even for the workman who not only does not design his own pattern, but never intends to do so, to have some general notions about the character of the drawing he proposes to use.

Transparency.—The first point to be kept in mind is that the material employed is transparent, and thus differs essentially from the substance of an ordinary picture. This gives the artist a range of colouring, and of light and shade, which is denied to the painter of pictures. At the same time, as glass is necessarily transparent, it will not do to have any portion so dark that it would be entirely devoid of transparency. In fact, the amount of light to be transmitted through the window is a very important consideration. If the building possesses but few and small windows, it will not do to exclude much of the small portion of light admitted; and on the other hand, should the amount of light entering be considerable, deep-coloured and low-toned windows not only conduce to that "dim religious light" which adds mystery and variety to colourless architectural forms, but they are exceedingly agreeable to eyes wearied with the garish light of the every-day world.

Adaptation to Site.—The character, then, of the edifice must be consulted, and it is no less necessary to adapt the designs in the windows to the style of the architecture. What would be pleasing in a Gothic building, would be ridiculous in a Renaissance edifice; and what would be suited to the lancets of an Early English chancel, would be incongruous in the large lights of a Perpendicular west window. A study of ancient glass, therefore, in connection with the architecture of the period, is essential to the perfection of designs for ecclesiastical windows at least, which form a very considerable portion of the whole number of works of this kind.

Another consideration that must enter into the calculations of the designer, is the aspect and situation of the window. In a window looking northward, a predominance of blue will be avoided, and more ruby and orange yellow will be allowable than if the outlook were in an opposite direction. Glass for a clerestory, or other high window, would naturally be of a different style, and ought to be more boldly executed than one which was intended to be placed at a short distance from the eye of the spectator. The ancient designers of glass, like the ancient painters, were not above calculating the effects produced by the probable position of the beholder, so that in a window which could only be looked at from some way below, the faces and limbs were lengthened to a most unnatural extent, in order that when foreshortened by the eye they might appear of a natural proportion. Such artifices must still be adopted if windows are in very awkward positions.

Bad Drawing not necessary to Good Glass.—Though in all these matters the work of old masters not only deserves study, but is absolutely essential to the production of good work, there is one point upon which it is necessary to guard the lover of the antique. No worship of mediævalism will excuse an imitation of the bad drawing and the false anatomy of ancient pictures. The painters of the present day, however much they may study and benefit by the instruction derivable from the works of the veritable Pre-Raffaelites, are not often guilty of the anachronism of imitating their drawing, so defective from a want of knowledge of anatomy. It is surely the part of a wise draughtsman to know how to "reject the evil and to choose the good," amid the varied riches left by the great but human giants of old time. The forms should be not only as good and as true as our present knowledge can make them, but they should also be pleasing; and this is the more necessary in glass-painting, for from the nature of the material the outlines are more strongly marked than they would be in the kindred art of painting or even in many cases of sculpture.

Geometrical Patterns.—But whilst thus only giving general hints and recommendations of study of the best models as the best, and in fact only, preparation for producing designs for those portions of windows that represent figures and scenes, we must remember that there are portions which are easier of accomplishment, more frequent in their occurrence, and about which it is possible to give more definite instruction. Some coloured windows are formed entirely of, and few are completely free from, patterns conveying pleasurable feelings of colour, form, and shade, but not intended to represent action or emotion. Many of these are made up of simple geometrical figures, and in most cases the greater the simplicity, the better the effect; but conventional forms of leaves and other natural objects, or of architectural ornamentation, are intermingled with a portion of arabesque in almost all windows containing human figures.

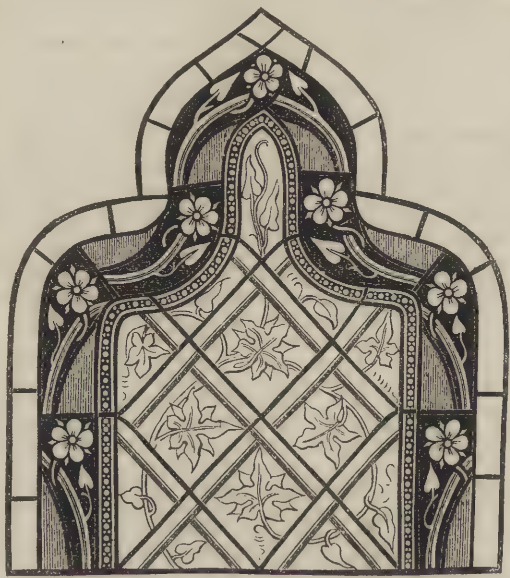


Fig. 1.—WINDOW IN PAINTED GLASS.

Example of Pattern.—A first attempt at glass-painting can scarcely be made with a better subject than we give in Fig. 1. Here the design is exceedingly simple and yet very effective. In the first place there is a tolerably wide margin of (so-called) white glass round the outside. The colour of this and of the quarrels in the original window is a light bluish-green, somewhat of the pleasing tone to be seen on the hedge-sparrow's egg. The longer slips between the diamonds are of rather a browner tinge, still very pale, transmitting a considerable amount of light through the whole window. The little beading parallel to the edge of the window is a dull yellow, corresponding to the tinge upon the stalks in the running pattern. This latter is evidently produced by the stain of silver (which will be explained hereafter). It will be seen on close examination that this broader ribbon of colour is made up of nearly triangular pieces fitted end to end, so that the two together make a rather long oblong piece. One of these triangles consists of a deep and bright green glass, scarcely shaded at all. The other is evidently originally of (so-called) white glass, on which the stems are stained (*i.e.* yellow), and the rest of the forms are marked out by very deep shades of brown, thus allowing the eye to suppose that the green is carried on beneath the stalks, which could not have been done, as will be seen hereafter, without great labour and a large quantity of leading. Thus the leading and the shades combine to carry out the forms intended, and with very simple shapes of glass of only two or three colours a most pleasing window is produced. The leaves on the diamond-shaped panes are, of course, formed by shades burnt in, as will be described hereafter.

It should be remembered that it is always necessary to have a margin of light-coloured or even transparent glass around the whole framework of the window, as otherwise a portion of the

design will be lost whenever the light comes in any direction excepting straight through the opening.

Working Drawing.—When the design is completed or fixed upon, it is necessary to make a working drawing the full size of the intended window. This is usually done in charcoal upon white paper. This material, of course, affords great facility for correction until it is finished and set, and it also is capable of marking strongly the depth of the lines. The French glass painters make their working drawings with black chalk on blue tinted paper, heightening the lights with white chalk. When this working drawing is completed, and the colours denoted either by their names or by small patches of paint, the next step will be to mark in the lines of the leading and the lines of the stanchions. These stanchions are iron bars crossing the window, fastened to and supporting the leading by which the various pieces of glass are kept together. These bars are usually at fifteen inches apart, and are seldom altered unless they interfere greatly with countenances or some other very prominent part of the picture. They then can be turned aside or removed a few inches, but it is astonishing how little the eye marks their interference when they occur at regular intervals. We remember one instance in which a village blacksmith had made his stanchions in zigzags, in order not to disturb a quarry-shaped pattern—a demonstration of rustic taste and skill that deserved encouragement. In some cases even, as in the Savoy Chapel, the stone mullions of a window are allowed to separate portions of outstretched limbs, without giving any feeling of discomfort to the beholder.

Leading.—The arrangement of the leading requires judgment and care. In much of the old glass we see leads running across limbs, faces, and plain surfaces of drapery, and this is imitated by some of those who copy the antique simply because it is old; but as there is every reason to believe that the ancients did not intend their pictures to be thus disfigured, but that these lines are merely the result of fractures, it is scarcely wise of the student of the old masters to adopt a system worthy only of the manufacturer of sham antiquities. Care should be taken then, in marking out the lines for the leading, not to interfere with the outlines of the design more than is absolutely necessary; at the same time it must be remembered that the heavy and thick glass that has to be employed requires frequent support, and that no very long and thin strips should be exposed to the strain from which they are liable to suffer when placed in the position assigned to them. The introduction of frequent folds into drapery, or a deep line of shadow, will often relieve the workman from those difficulties. Here it will be found that a design thoughtfully planned, with well-arranged breadths of light and shade, will already have an advantage in the mere mechanical part of the working over a drawing, which will also be inferior to it in the agreeableness of its result, and which errs artistically in what is technically called *want of breadth*, that is, the lights and shadows are too much cut up, causing a spotty appearance.

APPLIED MECHANICS.—XIV.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

FLOUR-MILLS.

WE propose in the present lesson to inquire into the mechanical principles of that very important class of machines which are employed in crushing or grinding.

The flour-mill has been selected, as being the most important machine of this kind. Flour-mills have received that attention to their mechanical perfection which machines so much used must have necessarily commanded.

The stones which are employed in grinding corn are of a special character. The millstone is a siliceous rock full of interstices or cavities, which retain the grain, and expose it to the action of the revolving stone. The intense hardness of these stones prevents them from being ground away, and having their particles mingled with the flour, as is the case when granite or sandstone, or other comparatively soft stones, are used for the purpose: a good pair of millstones can be used for twenty years. The principal quarry from which good millstones can be procured is at La Ferté, in the basin of Paris. We extract from "Tomlinson's Cyclopædia" the following interesting account of the manner in which these stones are procured. The bed of argillaceous sandstone in which the millstones are found "seldom yields more than three thicknesses of mill-stones; although spread over a considerable plain, it is not always of sufficiently good quality to be worked. The good stone is discovered by sounding. In some places it opens into vertical cracks, which allow the stones to be got out vertically, and these prove to be of the most durable kind. The works are quarries, not mines, for the loose nature of the superposed rock does not allow of the more economical method of driving galleries underground.

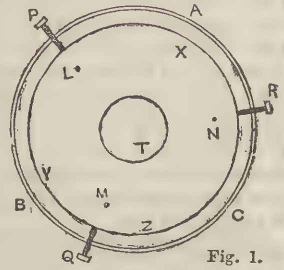


Fig. 1.

"The water, which is rather abundant in the works, is raised by means of buckets attached to balanced levers, which are worked by children, who raise the buckets from stage to stage. When the quarryman has arrived at the bed of millstone, he strikes it with his hammer. If the stone yield a good sound, it is known to be of excellent quality and large size. If the sound be dead or dull, it will separate in getting out. The man then gets out a mass of rock, and shapes it roughly into a cylinder, which, according to its height, will furnish one or two mill-stones; he sometimes gets three, but never more than that number; he then cuts a channel about four inches deep round this cylinder, for the purpose of separating it into two mill-stones, which he does by driving into a channel two rows of wooden wedges, which are gradually and equally driven all round, until the mass splits asunder. The man occasionally applies his ear to the mass, to ascertain that the line of fracture is following the right direction. When millstones of large size are required, the fragments of stone are dressed into their proper shape, cemented together, and united by iron bands. Stones of this kind are largely imported into England and America."

The diameter of the millstones most frequently used is four feet, and their thickness about twelve inches. In the composite stones about half the thickness only is composed of the siliceous millstone, the remainder consisting of plaster of Paris. The lower stone is carefully dressed to a flat surface, but the upper stone is made slightly hollow for a small distance from the central aperture, in order to admit the grain.

The surfaces of both stones are cut into grooves oblique on one side and vertical on the other, so that when the upper stone revolves, the edges of its grooves meet the corresponding edges on the lower groove like a pair of saws, and thus divide the grain. We proceed to describe the manner in which the millstones are mounted, and the mechanical contrivances by which the motion is produced and regulated.

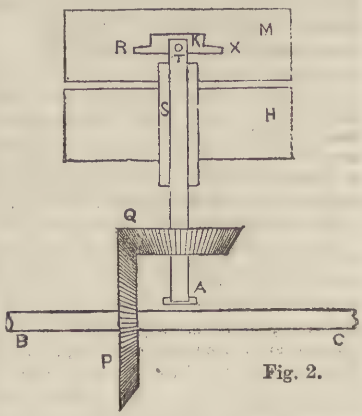


Fig. 2.

The lower of the pair of millstones is fixed, while the upper rotates. The vertical spindle which turns the upper stone passes through a hole in the lower stone, while the corn is introduced through the hole in the upper stone. We shall first describe the adjustment of the lower millstone (Fig. 1). A B C is the iron case, in which the lower millstone, X Y Z, is placed. The stone is held firmly by the screws P, Q, R. It is essential for the proper working of the mill that the acting surface of the lower millstone be exactly horizontal. This is to enable the pressure of the upper millstone to be perfectly uniform. The lower stone, instead of resting directly upon the bottom of the

case, is supported upon three screws, L, M, N; these screws work in holes, which have been tapped at the bottom of the box. Three points in space determine the position of a plane, consequently even though the lower surface of the millstone be uneven, the upper surface can be made horizontal. The mode in which this is accomplished is as follows:—By means of the set-screws P, Q, R, the millstone is placed perfectly central in the box; a pair of spirit-levels, at right angles to each other, are then placed upon the stone; by means of a spanner, the heads of the screws L, M, N are carefully turned, until the spirit-levels show the upper surface of the millstone to be horizontal. The set-screws P, Q, R are then finally tightened, in order to make the millstone firm, and the setting of the lower stone is complete.

The process here described of adjusting a plane by means of three screws like L, M, N is worthy of attention, as it is of the utmost importance in various parts of mechanics. It should be noticed that less than three screws would not be sufficient, and that more than three would be superfluous.

In Fig. 2 is shown in a diagrammatic manner the relative arrangements of the millstones and the mechanism by which the upper stone rotates. H is the lower stone, A T is the vertical spindle passing through H, which turns the upper stone M. B C is the shaft by which motion is communicated to the different pairs of stones throughout the mill. The fly-wheel of the engine which turns the mill is usually toothed, and gears into a pinion upon the shaft B C. If the mill be worked by water-power, then the shaft B C receives motion from a pinion, which is turned by a large toothed wheel on the axle of the water-wheel. This shaft communicates motion to each pair of millstones by the pair of bevelled wheels P, Q. The wheel P being larger than Q, the vertical spindle is made to rotate more rapidly than the shaft B C. Thus, if the wheel P has three times the diameter of Q, the vertical spindle will rotate three times as fast as the shaft B C. When a pair of millstones is to be thrown out of gear, the pinion Q is raised until its teeth are free from the wheel P. In order to allow of the sliding movement of the pinion upon the vertical spindle, the pinion is not keyed to the spindle. The nature of the connection is shown in Fig. 3. A represents the pinion seen from above. S is a key on the boss of the pinion, which fits into a corresponding groove in the shaft P; thus the pinion is free to slide up and down along the shaft, though when the pinion revolves, it must carry the shaft with it. A ring underneath the pinion, which can be raised or lowered by a screw, enables the machine to be thrown into gear or out of gear with facility. We shall presently see that the power possessed by the spindle of sliding through the pinion is of importance, for a more important object than that of a disconnecting gear.

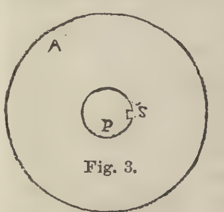


Fig. 3.

A (Fig. 2) is the step in which the lower end of the vertical spindle works. The upper bearing of the spindle is fixed in the lower millstone. The upper end of the spindle is not rigidly attached to the upper millstone. In fact, the upper millstone is attached by a kind of universal joint. Through the end of the spindle is a cross-piece T; the ends of this cross-piece are cylindrical. The bearings of these cylindrical ends are in a piece, K. Even this piece is not rigidly attached to the millstone. The cylinders R X, attached to K, work in bearings in the millstone. Thus the millstone is capable of rotating slightly about either of two horizontal axes at right angles, and therefore of rotating about any horizontal axis. By this ingenious arrangement the utmost facility is allowed to the upper millstone of adjusting itself, so as to work as smoothly as possible over the lower stone.

PRACTICAL PERSPECTIVE.—X.

It is intended in this lesson to show the method of putting into perspective the same object when its sides are placed at angles to the picture-plane, as shown in Fig. 48.

As the vanishing-points will in the present study extend far beyond the limits of the page, a diminished copy (Fig. 49) of the first working lines is given as a guide in starting. The lettering in this corresponds with that of the larger figure.

Having drawn the picture and horizontal lines, the line of direction, C S, etc., construct at S the angles C S C′ and B S B′, corresponding with the angles C A C′ and B A B′ in Fig. 48.

Produce the lines of the angles so as to meet the horizontal line in VP1 and VP2, and find the measuring-points, as already shown.

Proceed to project the square plan of the block by means of the vanishing-points and measuring-points, as in previous figures, and thus obtain the figure A B′ D C′. Draw the diagonals C′ B′ and A D, and produce the latter until it meets the horizontal line in the *vanishing-point for the diagonal*, V D. And now all the lettering will refer to Fig. 47.

From A set off E, and from B set off F, equal to the length which the plinth projects beyond the upper block. From E and F draw lines to the measuring-points, cutting A B′ in E′ and F′. From E′ and F′ draw lines to the vanishing-points, cutting the diagonals in *e*, *g* and *f*, *h*. Join these points, and the figure *e f h g* thus obtained will be the plan of the upper block.

At A erect a perpendicular of indefinite height, and on it mark *a*, the real height of the front edge of the plinth.

From *a* draw lines to the vanishing-points, and from B′ and C′ erect perpendiculars, meeting these in *b* and *c*.

From *b* and *c* draw lines to the vanishing-points, intersecting each other in *d*, which will complete the plinth.

On the upper surface of this, draw the diagonals *c b* and *a d*, and produce the latter until it meets the horizontal line in V D.

From *e* in the plan, erect a perpendicular, cutting the diagonal *a d* in *e′*. Then *e′* is the position of the angle of the upper block.

From *e′* draw lines to the vanishing-points, cutting the diagonal *c b* in *f′* and *g′*. From *f′* and *g′* draw lines to the opposite vanishing-points, intersecting each other (on *a d*) in *h′*. This will complete the plan of the upper block, projected on the upper surface of the lower.

Now, on the perpendicular A mark off A L, the real height of the upper block; and from L draw a line to V D, cutting the perpendicular *e e′* in *m*, which will be the *perspective* height of the object.

From *f′* and *g′* erect perpendiculars; and from *m* draw lines to the vanishing-points, cutting the perpendiculars in *n* and *p*. From *n* and *p* draw lines to the opposite vanishing-points, intersecting in *o*; and this will complete the projection of the object in the required position.

EXERCISE 35.

Put into perspective the object shown in Fig. 46, when standing on the right side of the spectator, at a distance within the picture, the front of the plinth to be parallel to the picture. The measurements to be as follow:—Scale, $\frac{1}{2}$ inch to the foot. Height of spectator, 6 feet; distance, 18 feet; side of plinth, 8 feet wide and 3 feet high; side of upper block, 6 feet wide and 8 feet high; distance on left of spectator, 4 feet; distance within the picture, 7 feet.

EXERCISE 36.

The same object to be put into perspective, when one side of the plinth is at 40° to the picture-plane. All the other circumstances as to distance on the left or right of the spectator and within the picture to remain the same.

Fig. 50.—The present subject is more an application of the last study than an absolute lesson, and therefore it is not lettered; so that the student may be thrown more upon his own mental resources, and become gradually accustomed to "think out" the working of perspective forms. Unless he does this, the whole of his exertions will end in his copying the diagrams; and then by far more harm than good will have been accomplished. The author has endeavoured to vary the lessons, and urges on the students the importance of *working every example to different measurements and under different circumstances* to those given in the text. It may sometimes occur that one line is absolutely hidden behind another; and the student may find himself in difficulty *if he depend only on the diagram* to know how it is that he gets *two* lines instead of one. He rubs out, repeats his work, and with the same result; the cause being that his object may have been placed $\frac{1}{16}$ of an inch more to the right or left of the centre of the picture, and that then the line previously hidden will become visible, and his result may be just as correct as the example.

Again, teachers who adopt these lessons (written by one who has spent twenty anxious years in teaching the subject) are recommended to use the black-board for general illustration

only; but, as soon as the most elementary principles are mastered, to give to the pupils different dimensions and distances to those from which the black-board lesson is worked, explaining at the same time what changes may occur in consequence of the difference of circumstances. By these means the students will

Now in this example the upper blocks are not so high as the lower ones, but are of precisely the same *width*, and are therefore worked from the same *plans*.

If they were different in width, additional plans would be required for them. As it is, let the plan be projected of the

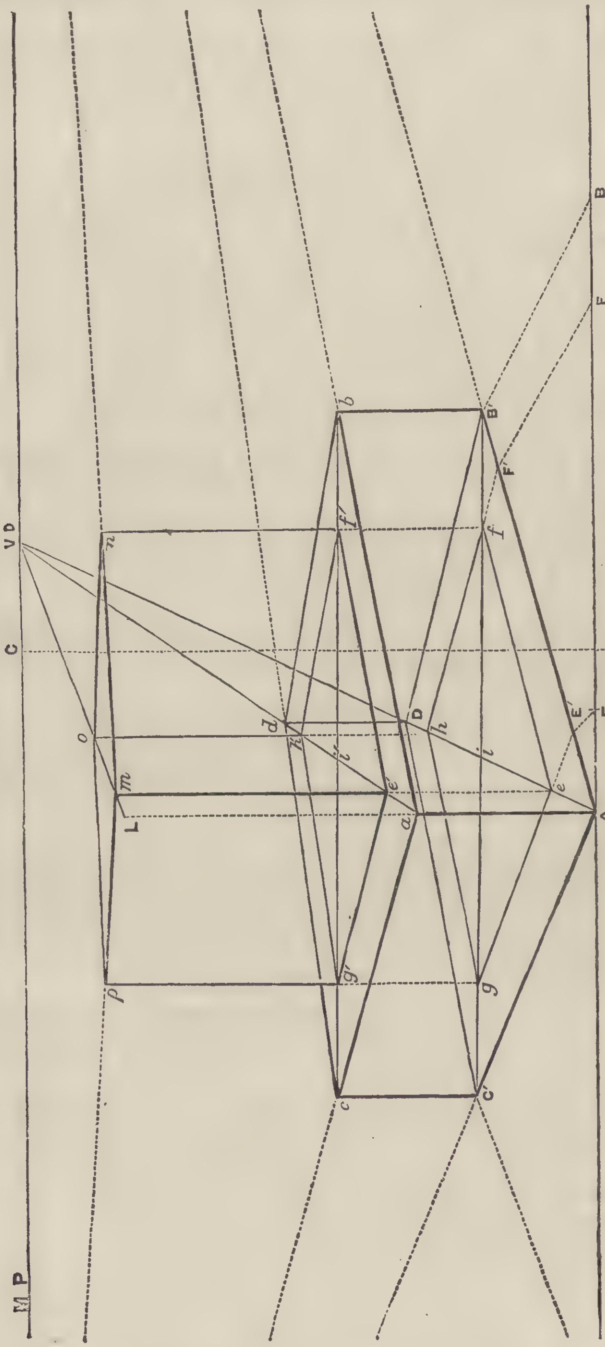


Fig. 47.

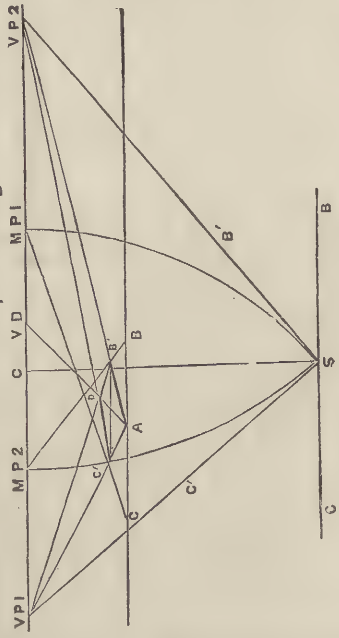


Fig. 49.

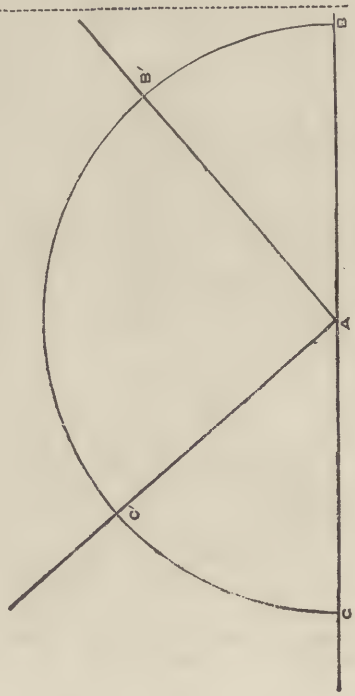


Fig. 48.

learn and become interested in perspective, which otherwise may be found difficult and irksome.

In Fig. 50, then, we give a simple application of the previous studies; for it will be seen that the base is the same as the object which forms the lesson illustrated by Fig. 46. But, as a *third* block is to rise from it, an additional inner figure is required in the plan. And, further, the capital of the pier is only the same subject as the pedestal turned upside down.

whole block in the first instance. Then, diagonals being drawn, the widths of (1) the first block and (2) of the pier itself are to be set off on the picture-line within the extreme points of the containing square. Then, from these points, lines drawn from the centre of the picture will cut the diagonals in points which, being joined, will give (1) the plan of the first block standing on the plinth, and (2) the plan of the pier itself.

Now if, as each process is pursued in the figure below the

horizontal line, the same system is followed at the given distance *above*, the corresponding effect will be obtained. Thus, when the plinth has been drawn, the abacus, or upper member of the pier, being the same in every respect but its height, is drawn in precisely the same manner, the lines proceeding to the centre of the picture downwards instead of upwards. And as perpendiculars are drawn from the points in the diagonals on the plan, they will cut the diagonals in the under surfaces of the blocks *above* the horizontal line in the exact points required. In this manner the whole object may be completed.

EXERCISE 37.

All the conditions as to height and distance of the spectator being the same as in the last figure, put the same object into perspective, when at a given distance within the picture.

EXERCISE 38.

Put into perspective the same object, when the sides of the plinth are at 40° and 50° to the picture-plane.

Fig. 51.—This subject is a simple sideboard. It will be seen that the blocks on each side rest on plinths, as the upper block does in the last lesson, and they will therefore be projected in the same way.

The slab forming the top of the sideboard, however, is of the same size as the plinths; and its projection on each side is therefore governed by perpendiculars raised from the angles of the plinths.

When the front edge of the top has been completed, lines are drawn from its extremities to the centre of the picture; and these would be terminated by a horizontal line drawn from A, the point at which a perpendicular raised from the distant angle of the plinth would intersect the line drawn to the centre of the picture.

But this back line would not be visible, since the back of the sideboard would rest on it, and the line which would be seen would be that of the junction of the upright back with the top of the sideboard. Therefore, within the point on the picture-line from which a line was drawn to the point of distance in order to find the distant angle of the plinth, set off the real thickness of the back, and draw a line to the point of distance. This will cut the receding line of the plinth in B; erect a perpendicular at B, and this, cutting the edge of the top in C, will give the place for the back line, C D.

At C and D erect perpendiculars, and at E erect a perpendicular, E F, equal to the height of the back at each end.

From F draw a line to the centre of the picture, cutting the perpendicular at C in G, and a horizontal from G will cut the perpendicular at D in H, the other end of the back.

But the back is not straight, but rises in the middle; therefore, having found I, the middle of the front edge, erect a perpendicular equal in height to the middle of the back.

From I draw a line to the centre of the picture, cutting the back line in K; and at K erect a perpendicular.

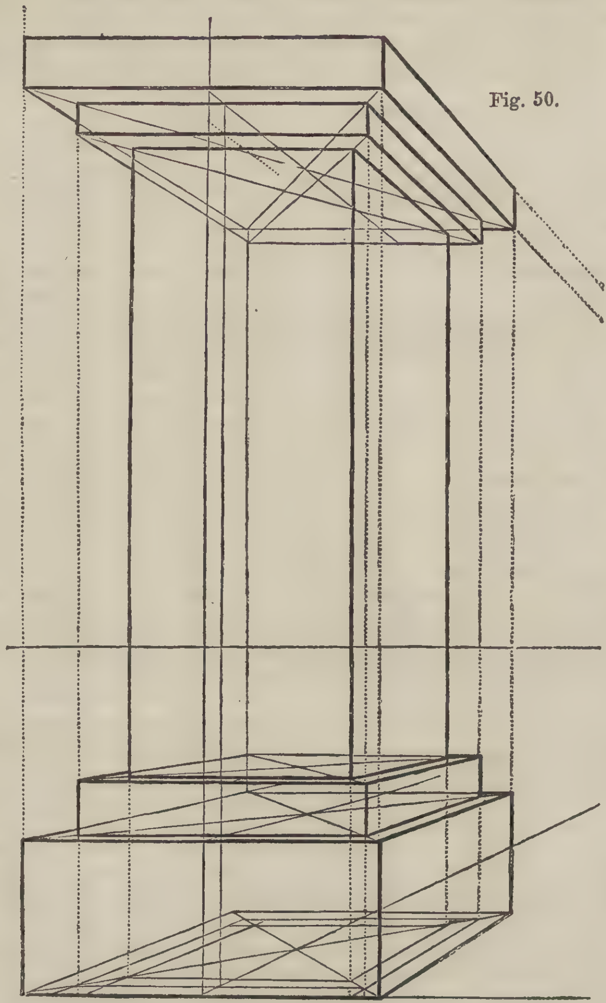
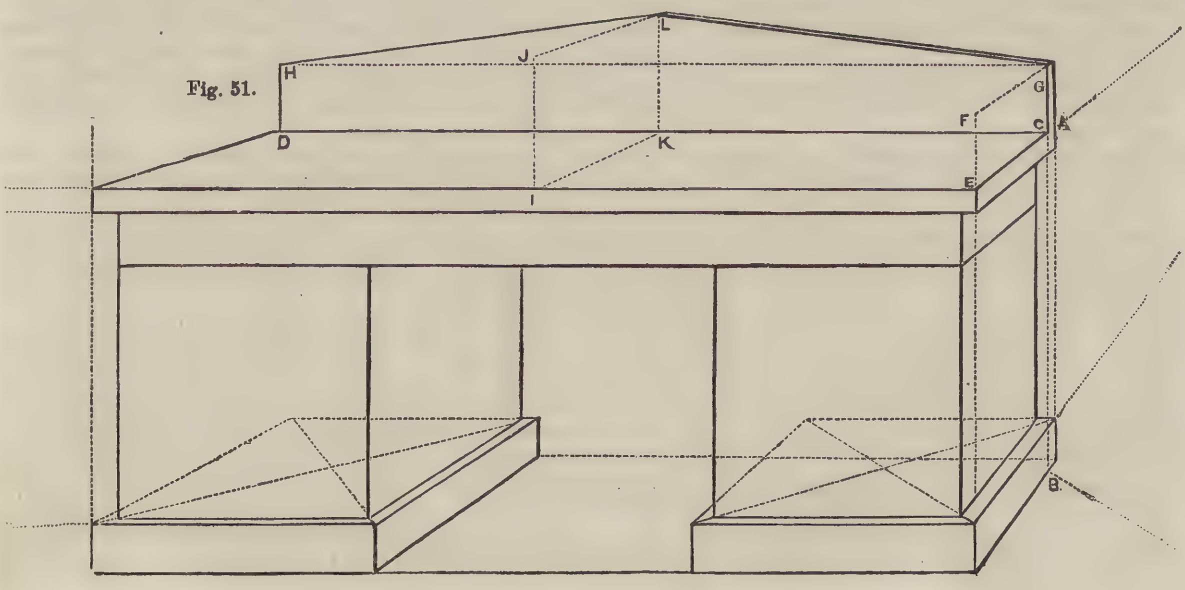


Fig. 50.

Fig. 51.



From J draw a line to the centre of the picture, cutting the perpendicular K in L; draw G L and H L, which will complete the perspective elevation of the back. The detail will be understood without further explanation, and this elementary form may be finished or varied according to taste.

EXERCISE 39.

Put the same sideboard into perspective when standing at a given distance within the picture.

EXERCISE 40.

Put into perspective the same object when standing at a given distance within the picture, its *end* being parallel to the picture-plane.

EXERCISE 41.

Put into perspective the same object when placed so that the front of it is at an angle of 50° to the picture-plane.

EXERCISE 42.

Put the same sideboard into perspective when its front is at 50° to the picture-plane, and when the object stands at a given distance within the picture.

CHEMISTRY APPLIED TO THE ARTS.—X.

BY GEORGE GLADSTONE, F.C.S.

LUCIFER MATCHES.

THOSE who are of middle age will remember seeing in their young days the tinder-box with its flint and steel, and the matches tipped at each end with brimstone—according to the present notions, a very clumsy apparatus for producing a light. The modern lucifer is indeed so vastly more convenient, and has so rapidly displaced the old process all the world over, that the old tinder-box—which was considered so indispensable till nearly the middle of this century—bids fair to be soon entirely forgotten. The lucifer was indeed truly described by a Chancellor of the Exchequer in a recent Budget as "among the most splendid boons—though it sounds a humble thing in itself—which science has given to man."

The remarkable cheapness of their cost tends, no doubt, to very considerable waste in their use, it having been calculated, as far back as 1856, that the daily consumption in Great Britain was about 240,000,000, equal to eight lucifers per day for every man, woman, and child. At that time only about fifteen years had elapsed since their invention. Now that a second fifteen years has passed, the consumption is probably much larger still. During the earlier term four-fifths of the lucifers used in this country were of foreign manufacture, very large quantities being made in Germany. Since then very extensive works have been established in England; and in addition to the home consumption, they form an important article of export to all parts of the world.

The trade may be divided into three principal classes:—1. The wooden match, to which the simple term "lucifer" is ordinarily applied. 2. The vestas, in which a thin wax taper is substituted for the wood. 3. The fusees, which are principally used by smokers for kindling tobacco.

The first is by far the most important manufacture—being twelve times as great as the second and third put together—and will claim principal attention.

The splints of wood are sometimes rectangular, and at other times rounded; the latter having a much neater and more finished appearance. The former are prepared as follows. Soft pine wood is taken and sawn up into blocks of a certain size, so as to fit the splitting machine. The block of wood being then fixed firmly in the proper receptacle, a frame containing a row of sharp-cutting points is, by turning a handle, made to pass over the wood in the direction of the grain, each point cutting into the wood to the depth of about the eighth of an inch. Another motion is then communicated to the machine, which brings a knife-edge against the block, and slices off a layer of the wood to a similar depth. The splints (at that time double the length they are ultimately intended to be) fall down complete into a receptacle below. These alternate actions of the machine continue rapidly, until the whole block is thus cut up.

The manufacture of the round splints may be considered even simpler than the foregoing. The cutting machine consists of a solid plate of metal, which is perforated with round holes as close together as possible, and slightly countersunk in front, so as to present sharp cutting edges. The piece of wood to be operated upon is placed immediately in front of the perforated plate, so that the cross section of the wood rests against it. Pressure is then applied at the other end, and the whole block of wood is ultimately forced through the perforations, coming out on the other side in the form of long thin round pipes, smoothly cut and highly compressed.

The splints are tied up in bundles of a thousand each, and then thoroughly dried by being left in a heated chamber for some time. The next process is ordinarily to dip the ends in melted sulphur, which is commonly done by hand, the dipper giving to the bundle a kind of twist which makes the ends spread out a little, so that they get coated all round with the sulphur, and do not stick together in cooling. Each end is dipped in turn; and when dry the bundles are cut through the middle by a circular saw, thus making them the exact length ultimately required. The object of dipping them first in sulphur is to supply a substance which will readily take fire on the ignition of the compound with which the end is afterwards tipped. The fumes of burning sulphur are, however, disagreeable, and some matches are therefore made without it. In this case the ends of the splints are slightly carbonised by pressing them for a moment upon a plate of red-hot iron, and then just touching them with some melted stearine or paraffin, a small quantity of which is at once absorbed by the wood. These burn even better than the preceding, as the wood then takes fire immediately, while in the others it does not until the sulphur is nearly burnt out. The stearine or paraffin is more expensive, but on the other hand a much less quantity will answer the purpose; and the matches so made are altogether preferable to the consumer.

The next step is to apply the material which is to be the source of fire, and which must be of such a nature as to take fire readily on the use of a moderate amount of friction. We must first consider of what this is composed, and then the manner in which it is applied.

This composition is made up into a pasty mass, the most important ingredient being phosphorus; but both the proportions and the subsidiary articles vary very greatly in different manufactories. The object is to make a paste, which when dried will not be affected by exposure to the atmosphere, which may be readily ignited with moderate friction, and which shall be sufficiently tenacious to adhere firmly to the end of the splint, until the wood has taken fire.

Ordinary phosphorus cannot be preserved in a dry condition in the air, as it rapidly oxidises and takes fire spontaneously, emitting very poisonous fumes at the same time. It has, therefore, to be kept constantly under water, and, except in combination with other substances, would be most unsuitable for domestic use.

Chlorate of potash, which is a highly explosive substance, is free from some of the objections attaching to phosphorus, and it is substituted for it by some makers. Most, however, use a little of each in their paste. The worst feature of the chlorate of potash is its readiness to explode on a very slight concussion, and the violence of its action throwing off sparks, which might prove dangerous. Those containing much of this article may be recognised by the sharp detonation with which they go off; those which are called "noiseless lucifers" contain no chlorate of potash.

These are the two principal light-bearing ingredients. The rest are glue or gum, to give them coherence; some fine sand or pulverised glass, to give increased friction; and some substances which will readily give up a large amount of oxygen, such as nitrate of potash, the peroxides of lead or manganese, and sulphide of antimony, to promote rapid ignition. Some mineral colouring matter is added, according to the fancy of the manufacturer.

It will be quite unnecessary to go into detail as to the relative proportions which may be used, for they may be varied almost infinitely. Even the most important article of all, the phosphorus, varies in quantity from 5 to 50 per cent. The larger proportions are generally to be found in those which contain no chlorate of potash. The lucifers made on the Continent are compounded with gum; but in England glue is generally used, because of the greater humidity of this climate.

The plan adopted in mixing the ingredients is as follows:—The glue is broken into small pieces and put into cold water, in which it is left to soak for some time; it is then boiled up

gently until thoroughly dissolved. The pot is then taken off the fire, and the required proportion of phosphorus is gradually added. It melts immediately with the heat of the watery glue, but it must be kept constantly stirred to make it mingle thoroughly, care being taken to keep it below the surface of the liquid. The other articles are then added, and the stirring maintained with vigour, as the compound thickens both with the cooling, and with the addition of the solid ingredients; it must, however, be kept in a pasty condition, and therefore the temperature is not allowed to fall below about 97° Fahrenheit.

The paste is then spread in a thin layer upon a flat table of marble or iron, which is kept just sufficiently warm to maintain the glue in a soft condition, until the dipping has taken place. If gum be used instead of glue, no artificial heat is required at this stage of the process, as it will not solidify by the mere cooling. The paste is spread evenly upon the table to an exact depth, so that in dipping the matches one shall not get a larger share of the composition than another.

The dipping is either done entirely by hand, or with the assistance of a frame. In the former case the workman takes a bundle of splints tied up with a piece of string, and by pressing it between his hands and imparting to it a certain twist at the same time, he makes the heads to separate a little, much in the same way as in the sulphuring process already described, though not to such an extent, as he is now dealing with wood of only half the length. The ends are then brought into contact with the paste, receiving only just sufficient for the purpose of striking a light. Consumers, however, generally prefer those matches which have a good head to them, and as in bundle-dipping they would all stick together if so much of the paste were used, the frame is used in preparing the better class of goods.

The frame or clamp consists of a series of separate pieces of wood fifteen inches long, one inch wide, and a quarter of an inch thick, the under side of which is covered with list, and the upper contains small transverse grooves one-fifth of an inch apart, and just sufficiently large to hold a splint. Children take these pieces of wood, and lay a splint upon each groove, and as soon as one is thus charged they lay the next one upon the top of it, and proceed as before. The list keeps the splints all steadily in their places, notwithstanding any trifling irregularity in their size. When the required number of rows is complete—containing in all about 1,500 matches—the frame which holds them together is screwed tight, and it is then passed on to the dipping department.

The dipper stands at his table of paste, while the frames are handed to and fro by boys. After dipping, they are left to dry for three or four hours in the air, and then are placed in a heated chamber for two hours, the temperature of which is maintained at from 80° to 90° Fahrenheit. The lucifers are by that time finished, and ready for packing, which is done by women and children. In the stoving and the packing great precautions have to be taken against fire. The people are supplied with cisterns of water in which to dip their hands if necessary, and each one has a small box of sawdust in which to thrust any lucifer that may be accidentally lighted.

Some patents have been taken out for cutting, dipping, drying, and packing the matches by machinery; and, independently of economical grounds, it is desirable that manual labour should be saved as much as possible, the work being both unhealthy and dangerous. In the best-regulated establishments these objections are, however, reduced to a minimum; and aggravated forms of the phosphorus disease are becoming very rare.

A more general use of the safety matches would perhaps be the most satisfactory way of obviating every objection, as there is a certain amount of danger attending the use of the ordinary lucifers at all times. If dropped upon the floor they will take fire when trodden upon; and even children have been known to poison themselves by sucking the paste off the ends. The absolute harmlessness of the safety matches is due partly to the use of the red or amorphous phosphorus instead of the ordinary description; and, secondly, to the mode of its application. This variety is not liable to spontaneous combustion; indeed, it will not burn except at a pretty elevated temperature, and it is not poisonous; so that it is free from all risk, both in the manufacture and in the subsequent use. From this description it will naturally be inferred that the action of the red is not so strong, and it is found necessary in practice to use a larger quantity, which considerably adds to the expense, phosphorus of either sort being very dear. A larger proportion of chlorate of potash and of the oxygen-supplying compounds is therefore substituted, if a match is to be made of the red phosphorus, which will take fire on any friction being applied in the usual way; but these are liable to the risk of ignition by friction accidentally applied, which will not occur in the case of the safety match. In these the chlorate of potash and one of the metallic salts is made into a paste with glue, and the match is dipped into it, as already described, while a second paste, consisting of the amorphous phosphorus, some more of the metallic salt, and a little glue, is made, and spread on the rubber in lieu of sandpaper. By thus dividing the ingredients, no action will take place, except on application to the rubber prepared for the purpose.

The vestas—the aristocratic match, as the Right Hon. Robert Lowe called them—are principally to be distinguished by the substitution of a waxed cotton for the wooden splint. The tapers are made by fixing a number of pieces of cotton thread, slightly twisted, in a frame, and then passing them through melted wax two or three times, until they acquire a coating of sufficient thickness; to make the surface of the wax smooth and bright, they are afterwards drawn through a perforated metal plate. The taper being less rigid than the wood, a larger proportion of phosphorus is required to be used in making the paste, so that less force may be needed when rubbing them on the sandpaper.

Fusees have cardboard or paper as a foundation. This is thoroughly saturated first with nitrate of potash; then cut into strips, and the paste applied to the edge by means of a spatula, after which they are laid out on a rack to dry. The nitrate of potash which has been absorbed by the paper, causes it to burn slowly and continuously, even though exposed to a strong current of air.

PRINCIPLES OF DESIGN.—XVI.

BY CHRISTOPHER DRESSER, PH.D., F.S.L.

WALL DECORATIONS (*continued*).

PURSUING our consideration of wall decorations, we notice that, just as the ceiling ornament must accord in character with the architecture of the room in which it is placed, so must the wall decoration be of the same style as the architecture of the room. Indeed, whatever we have said in a former lesson respecting the harmony of the ceiling decoration with the architecture of the building, applies equally to the ornamentation of the wall, if not even more forcibly, if this be possible.

It has been customary to arrange walls into panels when decorating them, and of this mode of treatment we give one illustration (Fig. 49); yet nothing can be more absurd than such a treatment, unless the wall is architecturally (structurally) arched. A wall may be so formed that some parts are thick, so as to give the required strength, while other portions are thin. In such a case the wall would be formed of arched recesses and thickened piers alternately. This being the case, the decoration should be so applied as to emphasise, or render apparent, this arched structure; but if the wall is of one thickness throughout, its division into arches is absurd and foolish.

We sometimes see great follies, and even gross untruths, perpetrated with the view of bringing about the so-called decoration of a room. Thus it is not unfrequently that we meet with imitation pillars, recesses, and arches as the so-called ornamentation of a room.

In low music halls we are not surprised by such decorations, for we do not look for truth or any manifestation of delicacy of feeling in such places. Falsity and the untrue appear in natural juxtaposition with the debased and the vulgar. Sham marble pillars, a fictitious and merely imitative architecture, an assumed and unreal, yet coarse and vulgar gorgeousness, are the natural adjuncts of immorality and vice; but such falsities cannot be tolerated in the abodes of those who pretend to purity and truth, nor in the buildings which they frequent; yet even the new Albert Hall has sham marble pillars (I say this to our shame), and but recently I visited a church near Edgware, in which there is a display of false decoration such as I never before saw. Here we find sham pillars, giving a false

architecture; sham niches, containing sham statues; sham clouds, forming an absurd ceiling; and almost every falsity which a falsely constituted mind could perpetrate.

How strange it is that in a church, where purity and truth are taught, the whole of the decorations should be a sham! It is said that if you want to hear a fierce quarrel, and to see true hatred, you must seek it in religious sects and theological discussionists. On the same principle, I suppose, we must prepare ourselves for a display of the worst art-falsity in the sacred edifice. Perhaps the idea is that of contrast. As the teetotal lecturer had a drunken man by him as a frightful example of what was to be avoided, so the decorations of this church may be intended as a warning, rather than as an example of what should be followed. Happily such churches as this are rare, and it can be truly said that ecclesiastical architecture and decoration have made great strides with us in recent years, and that in very many instances they are rigidly truthful as well as beautiful.

Fig. 49.

Before leaving the consideration of wall decorations, I must object to all imitations, as sham marbles, granites, etc., for no wall can be satisfactory which is to any extent a display of false grandeur; and this is curious, that in many cases it costs more to produce an imitation marble staircase than it would to line the same walls with the marbles imitated. I have known a case in which the imitation has cost double what the genuine stone would have cost, and such a case is not exceptional, for hand-polished work is always expensive. To imitations of marbles and granites, as I have already said, I strongly object, and of the genuine stone I am not fond, unless sparingly and judiciously used. My objections to its free use are these:—1st. Harmony of colour depends upon great exactness of tint. This exactness is rarely attainable in the case of two marbles. One stone may, however, be brought into direct and perfect harmony with a coloured wall, by the tint of the wall being carefully suited to the marble. 2nd. The true artist thinks less of the costliness of the material of which he forms his works than of the art-effect produced. Thus the old Greeks, who were full of art-feeling and refinement, coloured the buildings which they constructed of white marble, and they certainly thereby improved them; for colour, if harmoniously employed, lends to objects a new charm—a charm which they would not without it possess. I must further say, before leaving our present subject, that all walls, however decorated, should serve as a background to whatever stands in front of them. Thus they must retire even behind the furniture by their unobtrusiveness.

The order of arrangement in furniture must be this. The living beings in a room should be most attractive and conspicuous, and the dress of man should be of such a character as to secure this. Ladies can now employ any amount of colour in their attire; but poor man, however noble, cannot by his dress be distinguished from his butler; and, worst of all, both are dressed in an unbecoming and inartistic manner. Next come the furniture and draperies—the one or the other having prominence according to circumstances; then come the wall and the floor, both of which are to serve as backgrounds to all that stands in front of them. In decorating walls, or in judging of the merit or suitability of wall decorations, this must always be taken into consideration, that they are but enriched backgrounds; and it should also be remembered that the nature of the

enrichment applied is determined, to a great extent, by the character of the architecture of the building of which the wall forms a part.

We come now to consider wall-papers, which are hangings prepared with the view of enabling us to decorate our walls at comparatively small cost. I may confess that I am not very fond of wall-papers under any circumstances. I prefer a tinted or painted wall. Yet they are largely used, and will be for a long time to come. I have already said in a former lesson that if wall-papers are used they should not be joined together with straight lines, and that we ought to consider them as so much art-material which should be used artistically.

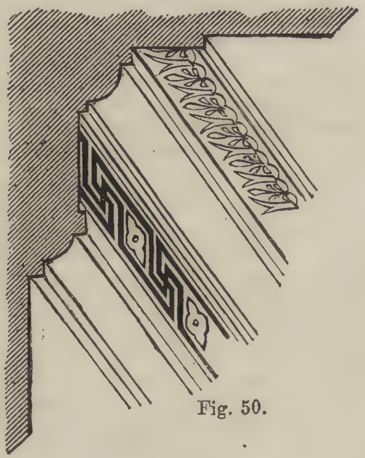


Fig. 50.

As to the nature of the pattern which a wall-paper should have, it is almost impossible to speak, as there are endless varieties; but as a rule it may be said that those consisting of small, simple, repeated parts, which are low-toned or neutral in colour, are the best. Most wall-paper patterns are larger than is desirable. The pattern can scarcely be too simple, and it should in all cases consist of flat ornament.

If the ornament is very good, and the pattern is the work of a true artist, it may be larger, for then the parts will be balanced and harmonised in a manner that could not be expected from a less skilful hand; but even if by the most talented designer, it must ever be remembered that he has designed it at random, and not as a suitable decoration for any particular room. The man who selects the pattern for a particular wall must choose that which is suitable to the special case.

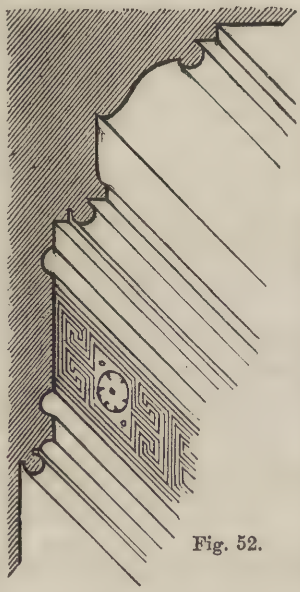


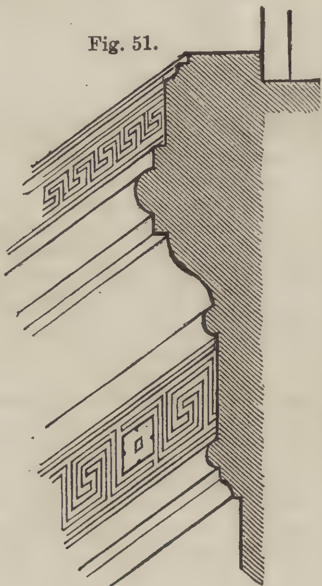
Fig. 52.

The effect of a wall-paper is materially affected by many circumstances. Thus, by the quantity of light admitted to the room, as whether the room is dark or light; by the aspect, whether it receives the sun's rays or does not; by the character of the light, as whether direct from the sky, or reflected from a green lawn, or red-brick wall. All these things must be considered, and what looks well in the pattern-book may look bad on a wall.

The best wall-paper patterns are those which consist of somewhat strong colours in very small masses—masses so small that the general effect of the paper is rich, low-toned, and neutral, and yet has a glowing colour-bloom, but these are rarely to be met with.

It was a fashion some time since to make wall-papers in imitation of woven fabrics, and this fashion has not wholly disappeared yet, absurd though it be. It arose through the accident of a designer of wall-paper patterns having been a shawl-pattern designer, and having a number of small shawl patterns on hand, which he disposed of as wall-paper patterns. A pattern which is suitable for a woven fabric is rarely suitable to a printed fabric, and especially when the one pattern is to be seen in folds on a moving object, and the other flat on a fixed surface. And at all times imitation by one material of another is untruthful, and it becomes specially absurd when we think that almost every material is capable of producing some good art-effect which no other material can. We should always seek to make each material as distinctive in its art-character as we can, and to cause each to appear as beautiful as possible in that particular manner in which it can most naturally be worked.

Fig. 51.



A word should be said about the particular character which a wall-paper pattern should have, but the remarks which I am now about to make will apply equally to all patterns employed as wall decorations. If we view trees or plants, as we see them against the sky as a background, they are objects which point upwards and have a bilateral symmetry (their halves are alike), or are more or less irregular in form, and when seen in this view we may regard them as natural wall decorations. Our wall patterns, then, may point upwards, as in Fig. 47, and be bilateral or otherwise; but it must be remembered that when the flowers of a primrose protrude from a bank, they are regular radiating, or star, ornaments. I think that it is legitimate for us to use on a wall star, or regular radiating, ornaments, as well as those having a special upward tendency.

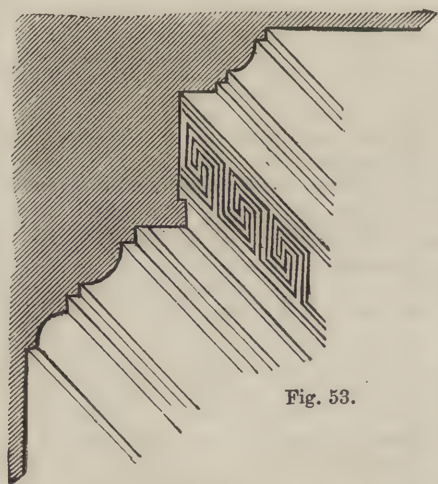


Fig. 53.

I have said that when seen from the side plants are bilateral, or are more or less irregular. As I have referred to plants as furnishing us with types of ornament, I should not be doing rightly were I to leave this statement in its present form, for the tendency of the vital force of all plants is to produce structures of rigidly symmetrical character; but insects, which eat buds and leaves, and blights, winds, and frosts, so act upon plants as to destroy their normal symmetry, hence we find an apparent want of symmetry in the arrangement of the parts of plants.*

Respecting the colouring of cornices, a few words should be said. 1st. Bright colours may here be employed. 2nd. As a

* Those who seek further information on this subject, will find it in the chapter on the arrangement of leaves, in Dresser's "Rudiments of Botany" (Virtue); Dresser's "Popular Manual of Botany" (Black); or Dresser's "Art of Decorative Design" (Day and Sons).

rule, get red in shadow or in shade, blue on flat or hollow surfaces, especially those that recede from the eye, and yellow on rounded advancing members. 3rd. Use for red either vermilion or carmine; for blue, ultramarine either pure or with white; for yellow, middle or orange chrome, diluted with white. 4th. Use red very sparingly, blue abundantly, the pale yellow in medium quantity.

Besides primary colours, none others need be used on the cornice. It is a mistake to use many, or dull, colours here, but gold may be used instead of yellow. With the view of explaining the principles which we have just enunciated by diagrams, we give four illustrations (Figs. 50, 51, 52, 53), and the coloured plate illustration of cornice, ceiling, and wall colourings, which forms the Frontispiece to this volume.

NOTABLE INVENTIONS AND INVENTORS.

XV.—THE SILK MANUFACTURE (*concluded*).

BY JOHN TIMBS.

ON arriving in England, in 1717, Lombe agreed with the Corporation of Derby to rent on a long lease for £8 a year an island or swamp in the river Derwent, 500 feet long and 52 feet wide. Here he erected, at a cost of £30,000, an immense silk-mill, now the property of the Corporation, the lease having expired. The foundations were formed of oaken piles, 16 to 20 feet long, driven close together by means of an engine which he contrived for the purpose; on these piles was laid a foundation of stone, on which were turned stone arches to support the walls. During the four years occupied in the erection of the mill, Lombe, in order to raise money to carry on the works, hired rooms in Derby, and in the town hall set up his machines, which were temporarily worked by hand, and by which he was enabled to sell thrown silk at much lower prices than it could be obtained from the Italians. By the time his large mill was completed he had permanently established the silk-throwing trade. In 1718 he obtained a patent, and, with the aid of his Italian workmen, was proceeding successfully in his business, when he died, cut off, as it was thought, by poison, through the agency of an Italian woman, whose business he had drawn away to himself. William Hutton, a native of Derby, whose early days were spent toiling in this very mill, states that Lombe lingered two or three years in agony, from the slow poison; and the woman was interrogated, and suspicion strengthened. He was honoured with a superb funeral. "He was a man," says Hutton, "of quiet deportment, who had brought a beneficial manufactory into the place, employed the poor, and at advanced ages, and thus could not fail to meet with respect; and his melancholy end excited much sympathy."

John Lombe was succeeded by his brother William, who, in a fit of melancholy, shortly afterwards shot himself. About 1726 the mill passed to his cousin, Sir Thomas Lombe, who in 1732, on the expiry of the patent, petitioned Parliament for a renewal, which was declined. The Government, however, granted the sum of £14,000 to Sir Thomas as compensation, on condition that he would prepare and deposit in the Tower of London an exact and faithful model of his machinery, for the inspection and advantage of those who might purpose constructing similar works. The Act authorising the issue of the money mentioned, among other circumstances which justified the grant, the great obstruction offered to Sir Thomas Lombe's undertaking by the King of Sardinia, in prohibiting the exportation of the raw silk which the engines were intended to work.

The accounts of the machinery of this immense mill, five storeys high, have been much exaggerated. The grand machine is stated to have been constructed with 26,586 wheels, and 96,746 movements, which worked 73,746 yards of organzine silk-thread with every revolution of the water-wheel whereby the machinery was driven; and as this revolved three times in each minute, the almost inconceivable quantity of 318,504,960 yards of organzine could be produced daily! Hutton's authority is, however, the best, for he served an apprenticeship of seven years in the mill, and he reduces the number of wheels to 13,384. The whole was moved by one water-wheel. Sir Thomas Lombe is stated by Hutton to have accumulated more than £120,000 by this mill. The chest in which John Lombe brought over to England his spindles and other machinery was long preserved in the mill which he built, but became the property of Mr. Llewellyn Jewitt, F.S.A. The chest is much older than Lombe's time; it is richly carved and painted, and, apart from its association with his name and career, is a remarkably fine example of art. It is engraved with Lombe's Mill, in "Stories of Inventors and Discoverers," 1860. Many throwing-mills have since been erected at Derby, and this branch of industry may be regarded as the staple of the town. Lombe's machinery has not, however, been used for many years; and improved machinery, which performs twice the work in less room, is now adopted.

In 1718 the silk-garden scheme was revived, when part of the estate of Sir Thomas More (Chelsea Park) was leased to a company, and 2,000 mulberry-trees were planted. Thoresby, in his Diary, 1728, tells us that he saw "a sample of the satin lately made at Chelsea of English silkworms for the Princess of Wales, which was very rich and beautiful." This scheme also failed; but the Clockhouse, in Lower Chelsea, was long after famous for the sale of mulberries from the trees planted for silk-rearing.

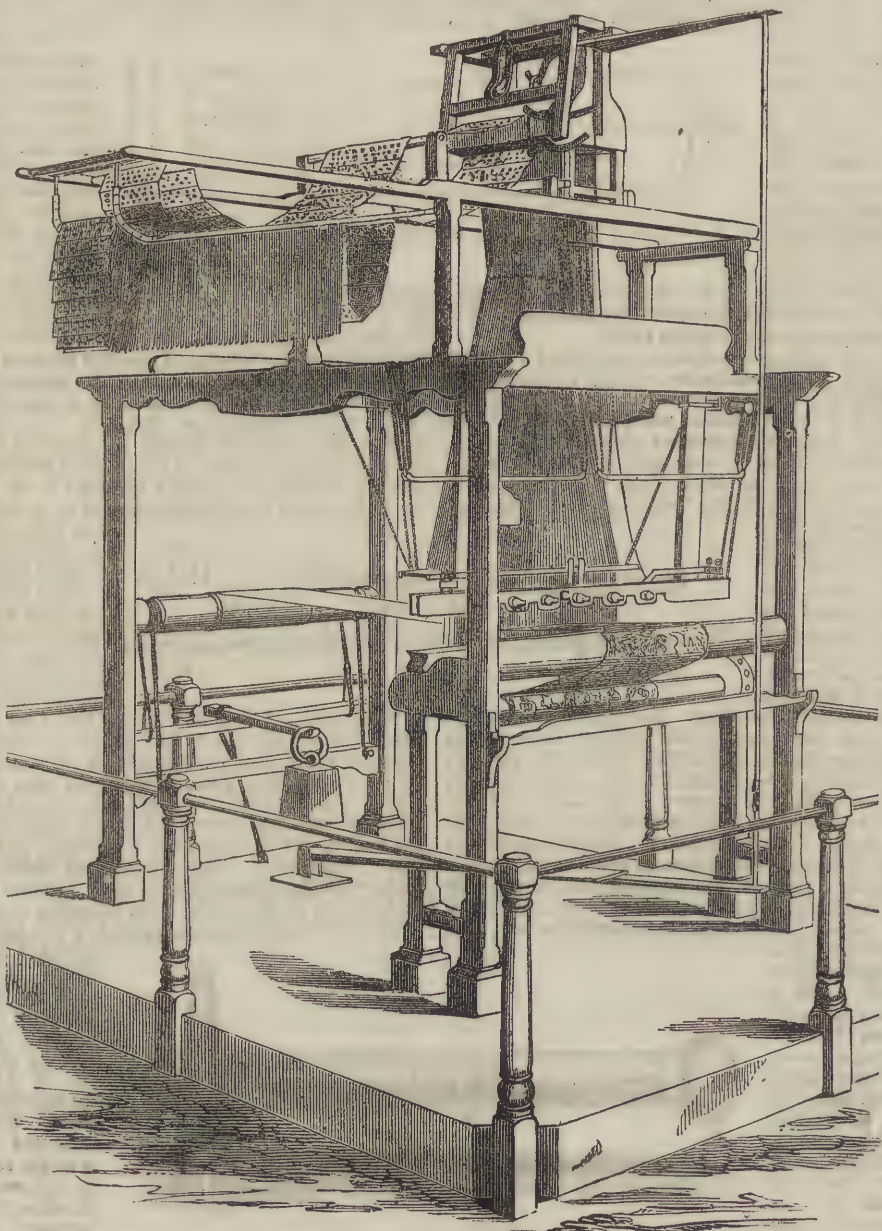
About the year 1789 nurseries of mulberry-trees were planted in several States of the American Union; but though the climate is not unfavourable to the rearing of silkworms, which are found in their natural state in the forests, the high rate of wages was an obstacle to this sort of employment, which is better adapted to the social condition of China, Italy, the South of France, and Malta, where the rate of wages is very low. In 1831 a small quantity of raw silk was exported from the American Union. The production of raw silk in British India is extensive; and labour is not only cheaper than in many parts of Europe, but three crops of silk may be taken in the year, while from countries west of India, including Turkey, only one can be obtained. The Chinese method of rearing silkworms has been introduced in St. Helena, but was soon given up. Some of the silk produced in France is believed to be better than that of any country in the world. The Italian silk is also highly esteemed. In Russia, Peter the Great formed mulberry plantations; and the rearing of silkworms was much encouraged by the Empress Catherine. In Bavaria and other parts of Germany, with the exception of Saxony, the silkworm is successfully reared as a commercial object; also in Sweden, where the silk is said to possess some valuable properties not found in that produced in a warmer latitude. In 1835 an attempt was made on a large scale by a company planting eighty acres in the county of Cork, with 4,000 mulberry-trees, but the design was soon abandoned. In 1839, Mr. Folkin produced at Nottingham some fine cocoons from eggs from Italy. Mr. Whitby, at Newlands, near Lymington, Hants, for many years reared silk with success from eggs of the large Italian sort, of four changes; and twenty yards of rich and brilliant damask manufactured from silk raised at Newlands have been presented to the Queen. The obtaining of a sufficient quantity of food for the worms at the right time has hitherto been the great difficulty of growing silk in England. In 1846 scarves were manufactured in Spitalfields from the produce of between 700 and 800 silkworms kept in an attic room at Truro; in size and weight the worms surpassing those in Italy, the cocoons larger, and the quantity of silk exceeding the Italian average.

British silks have long been equal to those of Lyons; the weavers of Spitalfields, Derby, Cheshire, Lancashire, and other districts in England being equal to French weavers; the deficiency, if any, is rather in the quality of the raw silk than in the manufacture of the article. Reeling the silk is a very material branch, which is never done in England, though silk-reeling is light and delicate work, well suited to women and children. It is generally supposed that the cocoons are injured in the carriage, but this is a fallacy. The worms are first carefully destroyed, and the cocoons are then packed in safety; so that the real difficulty is that of procuring silk carefully reeled from the cocoons.

Raw silk is the silk in its natural state when wound from the cocoon. It varies in fineness according to the number of cocoons reeled off at once to form one thread, the filaments of which are united by their viscid property. In the process of dyeing, the gum is discharged more or less, and the fibres become loose and unfit for weaving; the raw silk is therefore manufactured first into *singles*, *tram*, or *organzine*. By *singles* is signified one of the reeled threads twisted. *Tram* (from the French *trame*, or "shoot") is formed of two or more threads

twisted together, and is used for weaving ribbons for the shoot or weft. *Organzine* is formed of two or more *singles* twisted together in a *contrary* direction from that of its component singles. *Marabout* is silk thrown twice, and is made from the fine white silk from which the gum has not been boiled; that of the French is best. The preparation of the silk is the business of the throwster, a word formed from the word "throw," in the obsolete sense of "to twist, to twine."

In plain silk-weaving the process is much the same as weaving linen or woollen; but the weaver is assisted by a machine for the even distribution of the warp, which frequently consists of 8,000 separate threads in a breadth of twenty inches. The Jacquard loom, invented by a weaver of Lyons, has been the means of facilitating and cheapening the production of fancy or figured silks to an extraordinary extent. Patterns which required the greatest degree of skill and the most painful labour are produced by this machine by weavers of ordinary skill, and with little more labour than that required in weaving plain silks. Persian, satin, gros-de-Naples, ducapes, satin, and Levantine are the names given to plain silks, which differ from one another only in texture, quality, and softness. Satin derives its lustre from the great proportion of the threads of the warp being left visible, and the piece being afterwards passed over heated cylinders. Other varieties of silk goods are produced by mechanical arrangements in the loom, such as using different shuttles with threads of various substances, etc. The pile of velvet is produced by the insertion of short pieces of silk thread, which cover the surface so entirely as to conceal the interlacings of the warp and woof. There are several sorts of goods in which silk is employed with woollen materials, as poplins and bombazines.



THE JACQUARD LOOM.

Ribbons were early wrought with silk, and they formed a branch of the silk manufacture during its progress from Greece to Sicily, and from thence to Italy and Spain; but the ribbon trade seems first to have assumed distinct importance in France. The making of ribbons and small articles in silk long preceded in England that of broad silk. "The best ribbons made in France are those prepared for the English market; the home consumption is chiefly of less costly goods." ("Penny Cyclopædia.") But many ribbons are produced in Coventry which equal in quality their foreign rivals of the same make.

The perseverance of our manufacturers long since enabled them to ship British bandana handkerchiefs for India. In the printing of silk handkerchiefs there has been great improvement; and most of the India handkerchiefs are now printed in England.

On the steam-factory system, the manufacturer gets every preparatory process done; and by steam-power one-half of the weaving process itself—the shooting down—all that is left to the weaver being the picking up and attendance. The profitable application of steam-power to silk-weaving was long considered to be almost impossible, so large a portion of time being consumed in the handling and trimming of the silk, in proportion to the time that the loom is in motion, and a consequent waste of power; but steam has become the chief motive power of the ribbon as of other manufacturing districts. Jacquard steam-looms are employed in making light figured ribbons with great precision and beauty.

The silk culture of France has occasionally suffered a severe check in consequence of epidemics among the worms, and the production of unhealthy eggs. These interruptions, however, are generally very soon overcome, and this branch of French industry usually attains to great prosperity.

OPTICAL INSTRUMENTS.—VII.

BY SAMUEL HIGHLEY, F.G.S., ETC.

THE OPHTHALMOSCOPE.

I HAVE previously stated that where the diagnosis of an eye indicates defects or complications that place its legitimate treatment within the domain of the surgeon rather than that of the spectacle-maker, much may be learnt by the use of the ophthalmoscope; but as its indications must be interpreted by anatomical experience, I shall only describe the optical arrangements of this instrument, and refer all who wish to become acquainted with its use to the excellent practical treatise of Zander, an English translation of which has been edited by Mr. R. B. Carter.

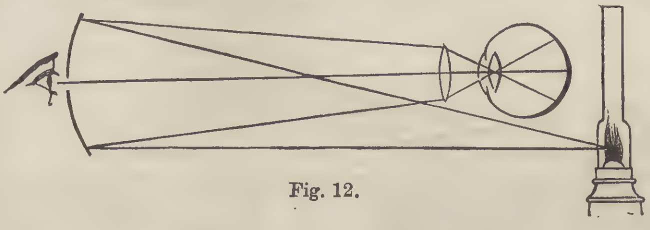


Fig. 12.

Liebreich's Ophthalmoscope.—The object of this instrument is to illuminate the interior of the eyeball, and then be able to observe a magnified image of its various parts.

In its simplest form the ophthalmoscope consists of a concave mirror an inch and a half in diameter, silvered at the back by Liebig's or Petitjean's process, pierced in its centre with a round hole of about $\frac{1}{10}$ inch in diameter, and having a focal length of about 6 inches. Behind the mirror is a support for eye-pieces, which may be convex lenses of 10 or 12 inches focus, or concaves of 6 to 12 inches focus, taken from the "trial case." This is used in conjunction with two "object-glasses," which are convex lenses, one of about $1\frac{1}{2}$ to 2 inches focus, and the other $2\frac{1}{2}$ to 3 inches focus, of about the same diameter as the mirror. The mirror and object-glass may be packed in an ebonite box not exceeding the size of a small watch, and then constitute the most portable form of the ophthalmoscope. In using this, the patient is placed in a dark room, face to face with the examiner, an argand lamp is placed beside and a little behind the patient's head, with the flame on a level with his eyes. The examiner places his eye close behind the aperture in the mirror, and then while about a foot distant from the patient directs the light of the lamp into the eye under observation. Should the relative refractive power of the eye of the observed and observer require it, suitable eye-pieces may be fitted behind the mirror. By approximating the mirror nearer and nearer, the cornea, lens, vitreous, optic nerve, yellow spot, intra-ocular vessels, etc., may be successively examined, and any pathological symptoms noted. This is termed "*the direct method*," the natural lenses of the observed eye forming a convex triplet, which gives an erect, virtual, magnified image of the parts seen. By employing one of the object-glasses (held between the finger and thumb of the observer's left hand, about an inch from the patient's eye, with the other fingers resting against the forehead to steady the lens) a larger field of view is attainable, with greater facility for observation. By proper adjustment of the mirror an inverted real image of the parts is seen. This is termed "*the indirect method*" of observation, and it must be observed that the rays of light reflected from the *fundus oculi* strike the object-glass, and form the inverted real image—in normal eyes *at*, in myopic eyes *within*, and in hypermetropic eyes *beyond*, the focal length of the object-glass. Should the eye of the observer be defective, the inverted image will be improved by employing a suitable convex eye-piece. Fig. 12 shows the general arrangement of the ophthalmoscopic apparatus, and some interesting matters relating thereto will be found at page 53 of Vol. VI. of THE POPULAR EDUCATOR, under the head of "Recreative Science."

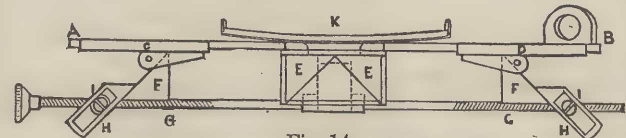
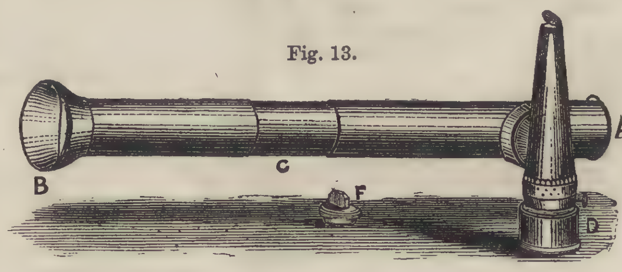


Fig. 14.

Beale's Demonstrating Ophthalmoscope.—The inconvenient necessity for making ophthalmoscopic observations *in a dark room* has been entirely obviated by an arrangement recently devised by Dr. Lionel Beale, F.R.S., Physician to King's College Hospital—shown in Fig. 13. This consists of a telescopic tube C, about one inch diameter, to the upper end of which a small paraffin lamp, furnished with a metal chimney and a bull's-eye lens, is attached by a rotating fitting, to allow of the observing tube being inclined at any convenient angle, while the chimney stands perpendicular. The rays collected by the bull's-eye are projected on a silvered mirror pierced in its centre with a small aperture. The end of the tube B, which slides or adjusts on C, is fitted with a piece of wood shaped to the margin of the orbit of the eye. On this end being applied to the patient's eye, the interior of the eye becomes perfectly illuminated by the light reflected from the mirror, and a magnified image of the *fundus* is obtained by means of an object-glass of $2\frac{1}{2}$ or 3 inches focus, fitted to the lower end of the tube C, and observed through an aperture at A, in front of which an eye-piece may be fitted when desired. An accurate focus is obtained by sliding the tube B on the tube C, the average point of focus being indicated by a mark on the tube C. The object-glass is mounted so that it may swing on a vertical axis, and be inclined so that the reflections from its anterior and posterior surfaces (which would interfere with the distinct image of the retina) may be thrown out of the field of vision, an inclination of less than a quarter of an inch being sufficient. This adjustment also prevents reflections from the lenses of the patient's eye becoming inconvenient. It should be observed that a plano-convex lens, with its plane surface towards the observer, thus mounted, reduces the annoyance from reflection to a minimum. When this apparatus is not in use, the reservoir of the lamp D is unscrewed, and plugged with a screw shown at F. The chimney and burner are turned horizontal with the telescopic body, so as to make the arrangement portable, for packing away in its travelling case.

Fig. 13.



This ophthalmoscope can be held in the hand, or it may be mounted upon a stem or tripod stand. It can be used in any room in *full day-light* or *when lamps are lighted. This arrangement entirely obviates the necessity of the dark room for ophthalmoscopic observations.* The eyes may be examined when the patient is in the recumbent posture as well as when sitting or standing, and in many cases without using atropine. When an observation is to be made the observer should request the patient to direct the other eye so that he may see distinctly some object on a wall from 8 to 10 feet distant, as a spot in the pattern of the paper, or a red wafer or piece of sealing-wax placed there for the purpose, about one foot higher than the level of the eye of the patient. The patient should be told to look, now a little above or below, to the right or to the left of this mark, until the optic disc, with the vessels, comes well into view; in many instances this will be immediately. The reason for preferring a distant object to a near one (as a ball attached to the end of a bar connected with the ophthalmoscope itself) is, that the *pupil dilates*, while it will contract if a near object be selected; and then by reason of its smallness, a good

view of the disc cannot be obtained without the previous use of atropine. This is the most convenient form of ophthalmoscope for clinical demonstration.

Laurence and Heisch's Binocular Ophthalmoscope.—In the use of the ordinary arrangement, the details of the fundus appear to be all in the same plane, so that the indications of abnormal elevations or depressions must be, as it were, translated to the mind of the observer by noting the change of plane, to secure perfect definition of each part while focussing. But if both eyes of the observer are brought into play, then the various parts will be brought into natural or stereoscopic relief, and the observation greatly facilitated. To this end Dr. Giraud-Teulon contrived a binocular ophthalmoscope, but did not provide an adjustment for difference of distance between the eyes of different observers; so that the two images could not, with his instrument, always be combined, except by a forced convergence of the eyeballs, which entails fatigue. This serious defect has been remedied by the adjustments provided in the arrangement of Laurence and Heisch. Beyond the greater accuracy of vision obtained by the perception of relief in the object viewed, a greater amount of light, with a more extended field of vision, is also secured. The essential parts of the instrument are shown in Fig. 14.

In using this arrangement the lamp is placed behind and above the head of the patient, in a line central with the observer. The instrument is held horizontally, so that the light from the lamp is reflected into the eye of the patient by means of the perforated mirror K. The image of the fundus is received upon the reflecting surfaces of two rectangular prisms E, E, placed behind the aperture in the mirror, from whence each prism reflects an image to the prism F F, from which each image is reflected into the eyes of the observer, placed close to these "ocular prisms." The ocular prisms F, F can be made to slide on a bar A B, and coincide with the optic axes of the observer's eyes, while simultaneously, by means of a slot and nut, and an endless screw adjustment H I, H I, the prisms are tilted to a suitable inclination for perfect observation from the reflecting surfaces. Convex eye-pieces, 8 and 10 inches, are provided, which can, when desired, be placed in clips in front of the ocular prisms. This arrangement may be used for the "direct" or the "indirect" method of observation.

The method of placing this instrument in adjustment for *each* observer is as follows:—

See that the nuts I, I are in the centre of the slots H, H; if not, bring them there by turning the screws G, G. (If care be not taken on this point, the instrument may be strained in adjusting the slides.) Having carefully measured the distance between the pupils of the observer's eyes, move the slides C and D till the marks on them correspond to that distance on A B. Thus, if the observer's pupils be 2·4 inches apart, the slides must be set at two divisions from the lines marked 2 inches. Great care must be taken to place them equi-distant from the centre. Now turn the screws G, G, till the nuts I, I again occupy the centre of the slots H, H. Place a light about eighteen inches in front of you, and holding the instrument quite horizontally, look through the prisms F, F. Two images of the light will now be seen. Ascertain that they are of equal brightness, by first shutting one eye, and then the other. If they are not equally distinct, it is a sign that the correct distance between the pupils has not been taken, and the slides must be moved till the images are equally bright: now turn the screws G, G. and the images will approach each other; when they perfectly coalesce, the instrument is adjusted.

There are other modifications of Liebreich's ophthalmoscope, which are designated by the names of the modifyers. At the Cambridge meeting of the British Medical Association Mr. Ernest Hart exhibited a demonstrating ophthalmoscope, somewhat on the plan of Beale's, but it was not by any means as portable or conveniently arranged.

BRICK AND TILE-MAKING.—I.

TERRA-COTTA, BRICKS, AND TILES.

BY GILBERT R. REDGRAVE.

CLAY, which is the result of the disintegration and attrition of the various primary rocks, is widely distributed over the earth's surface. It is found in almost every degree of impurity among the more recent deposits, and in a state of comparative purity in the coal measures and lower oolite—as a soft or friable earth in the former, or consolidated into rocks of considerable hardness and durability in the latter formation. Its colour varies, according to the quantity it contains of lime, iron, or bitumen, from almost pure white, through every shade of red, blue, and brown, to deep black.

The employment of clay by the potter dates from the most remote periods, for not only do we everywhere find the simple earthen vessels which man requires for his domestic wants associated with the earliest traces of civilisation, but we are expressly told in the Bible that with bricks moulded from clay the dwellers on the plains of Shinar began, 4,000 years ago, the famous "tower whose top should reach unto heaven."

It is our intention in the present series of papers to treat of clay as used only for structural purposes, and this we propose to do, not historically, but solely with the view of bringing under the notice of our readers the processes now most commonly practised in different parts of the country for manufacturing from clay the materials known as bricks, tiles, and terra-cotta.

Pure clay, which is, chemically speaking, a hydrous silicate of alumina, contains about 47 parts per cent. of silica, 40 parts of alumina, and 13 parts of water. This is very nearly exactly the composition of the substance known as kaoline, or china-clay; but fire-clay, pipe-clay, and potters' clay, are all comparatively pure silicates, having, however, a much larger proportion of silica than kaoline. The purer clays are, of course, selected for the best descriptions of pottery and terra-cotta; while the earthy clays, or loams, and the clays largely impregnated with iron and lime, which occur chiefly in the more recent formations, are used in the manufacture of bricks, tiles, and the commoner kinds of pottery. Commencing our remarks with terra-cotta, which is derived from two Italian words, *terra*, "earth," or "clay," and *cotta*, signifying "baked," or "burnt," we may state briefly that all the finer and better classes of prepared clay goods really come under this head. The difference between bricks and terra-cotta is an imaginary rather than a real one. Some would have it that terra-cotta is a vitrified brick, or a brick the silica contained in which, owing to its having been burnt at a high temperature, and to its being mixed with certain proportions of alkali or other flux, has been more or less converted into glass, as in the best stoneware. This definition, however, is far from being accurate, as terra-cotta is rarely if ever vitrified, except on the surface; and a better distinction would be to assume that all fine-grained clays which will resist a long-continued firing, and burn so hard as to become incapable of being scratched with the point of a penknife, may be regarded as terra-cottas; while the siliceous, porous clays, which would fuse at a high temperature, and admit easily, when burnt in the ordinary way, of being scratched with the knife, may be classed with the brick-earths.

Terra-cotta is generally made either of pure clay, which burns of a white or pale yellow colour, or from impure clay, which, owing to the presence of oxide of iron, burns to some shade of red. Much of the terra-cotta in England is made from clay found in the coal measures, called fire-clay, which occurs in beds under each seam of coal. The more recent clays of Dorsetshire, from the neighbourhood of Poole, and those from the southern districts of Devonshire, are also frequently used, together with the clay of Northamptonshire, for this purpose. We will glance in the first instance at a manufactory of terra-cotta from fire-clay, which may fairly be regarded as representative of this class of ware.

In almost every coal-field, without exception, large quantities of fire-clay are raised annually, and carried to spoil as a waste product. The utilisation of these spoil-banks probably led those interested in such matters to make experiments with the clay, and they must soon have found how admirably it was suited for all purposes where great strength, durability, and powers of resisting heat were of value. In course of time brick-works and terra-cotta works became necessary adjuncts of many of our great collieries; and in this way, in the neighbourhood of Glasgow, Newcastle, Leeds, Tamworth, and many other colliery districts, large clay-works are now in operation. The fire-clay, as it is dug, is hard and compact, of a greenish grey colour, sometimes almost black, has a very irregular shiny fracture, and an unctuous greasy feel, with little taste or smell. It is spread out in layers at the mouth of the pit, and picked or sorted into heaps—such pieces as appear brown and mottled

being rejected as containing iron, while those which have a dull fracture and feel gritty to the touch are put on one side for drain-pipes, fire-bricks, and the commonest kinds of ware. Only the best bright clay is used for terra-cotta; and it is thought by some that it is improved by being exposed during the winter months to the action of the weather, which causes it to "fall" or split up into fragments, and thus renders the subsequent grinding a simpler and cheaper operation than crushing the hard dry clay. We believe that this latter advantage is all that is gained by the weathering.

To prepare it for use, the clay is crushed to a fine powder under an edge-runner, or by means of Carr's disintegrator, or some simple crushing machine, and with it is ground up a certain proportion of some refractory substance, such as previously burnt pottery, which may form from one-quarter to one-fifth of the entire mass. The degree of fineness to which this grinding is carried varies very considerably in different manufactories and districts. The coarser ground clay seems on the whole to stand the firing the best, and to dry more rapidly than that which has been very carefully pulverised. We may here point out the object of adding to the fire-clay the broken pottery. It is done mainly with the view of counteracting the excessive shrinkage to which all tough, close-grained clays are liable, as it is obvious that clays which have already been once fired have become contracted to the utmost, and therefore the addition of considerable quantities of them to the raw clay tends to partially prevent it from shrinking. Another motive frequently given is, that "grog," as it is termed, opens the pores of the clay—*i.e.*, that in drying it facilitates the expulsion of the water—it also uses up a waste product, saves a little fuel, and, by giving a certain amount of unalterable matter, helps to retain the clay in the form in which it has been moulded, obviating thereby undue contortion under firing. For highly refractory goods, such as fire-lumps and fire-bricks, the materials are usually much more coarsely ground than for terra-cotta.

The ground clay, then, having been, by a sieving or dressing process, separated into various degrees of fineness, the finer portions are passed by an elevator or otherwise moved into a pug-mill. Here the clay-dust receives the proper proportion of water; and it is thought by some that better results are obtained by using hot water and steam than cold water alone. We believe that abroad it is usual to introduce into the water at this stage a small proportion of potash or soda; and we are convinced that our English manufacturers, when using fire-clay, might copy this practice with advantage. In mixing light powdery clay with water, there is frequently great difficulty in effecting a proper and uniform distribution of the moisture. This has been successfully overcome, however, by causing the mixture to take place on a large flat disc; on this the ground clay is gradually damped by numerous fine jets of water, with which it is brought in contact while it is gently spread and turned about by means of revolving arms or scrapers. The wetting takes place on the outer portions of the disc; and by the action of the scrapers the moistened material is slowly conducted into the barrel of a pug-mill, the orifice of which is immediately beneath the centre of the mixing table.

On issuing from the pug-mill, the clay is ready for immediate use; but there is no doubt that by employing rather more water than is now done, and placing the clay for a time in tanks or pits, till the superfluous moisture had evaporated, a mellowed and more plastic substance would be obtained. This, we may add, is a natural inference from the advantages gained from slipping the clays for the preparation of fine bodies, which process we shall refer to when we are treating of tiles. From the pug-mill the clay is conveyed to the moulder or modeller, where it undergoes a further manipulation at the hands of a sturdy labourer, who cuts from it repeatedly with a wire cutter portions as large as he can conveniently lift, and dashes them back with great force on to the parent lump. This operation, called "wedging," or "slapping," renders the clay more homogeneous, and expels any lurking traces of air and unnecessary moisture.

The moulds for terra-cotta are, we believe, for all hand-pressed work, invariably made of plaster of Paris; they are usually about two inches in thickness, and are therefore, for all but very moderate-sized pieces, very cumbrous and weighty affairs. It is unnecessary here to allude to the preparation of the plaster of Paris, as it is not now considered a branch of the terra-cotta manufacturer's business, though formerly it was customary to boil the plaster-stone at the works. This material is, of course, owing to its power of rapidly solidifying on admixture with water, admirably suited for the moulder; and it has, in addition to this setting power, a wonderful amount of porosity, which enables it to suck out the water from the damp clay, and thus permits of its removal from the mould in a shorter space of time than any other quick-setting cement. It is a fact not so universally known as it deserves to be, that the less water used in mixing up or "gauging" the plaster the denser and harder will be the resulting mould; while plaster which has been mixed with a superabundance of water, though it sets apparently almost as rapidly as that with less water, is much more porous and spongy, and consequently has far less wear in it than if it had been gauged stiffer. Plaster is, to a certain extent, soluble in water—about one part of plaster will dissolve in between 400 and 500 parts of cold water—and the long continued action of the wet clay, and the friction in forcing it in and out, speedily wears away the surface of the mould. It seems strange that, with the knowledge we possess of the substances which will harden plaster, such as alum and borax, and with our numerous hard-setting cements, we have not found some better material for mould-making than plaster of Paris, which forms no inconsiderable item in the cost of the manufacture of pottery.

Before going into the question of the moulding of the clay, it will be necessary to revert for a short time to the subject of shrinkage, and to its practical bearings upon the preparation of the models for any work in terra-cotta. The shrinkage has been scientifically explained by assuming that on the expulsion of the water the particles of clay mechanically re-arrange and distribute themselves over the space which it before occupied. Pure fire-clay contracts between the time of going into the mould and issuing thoroughly burnt from the kiln as much as one-eighth of its lineal dimensions; of this shrinkage, about one-half takes place in its green or raw state, at ordinary temperatures, before going into the kiln, and the remaining half during the firing. By the admixture of some definite proportion of previously burned clay, or other unalterable substance, this contraction may be, as we have already seen, considerably reduced; and by this means some makers modify the total shrinkage to one-twelfth lineally. The difficulty of thus artificially reducing the contraction is that workmen are so careless that the proportion of "grog" used is never twice alike, and the scale adopted for the preparation of the models becomes thereby wholly unreliable.

The plan we recommend in using terra-cotta is to send to the manufacturer a model of some plain moulding, and also one of a piece of highly-enriched work, requesting him to produce from moulds made on these models three specimens in terra-cotta of each. On the receipt of these pieces, together with the models originally sent, it becomes possible by measurement and a system of averages to find out the exact amount of shrinkage for which allowance must be made in the ware furnished by this manufacturer. If, for instance, the original model of the plain moulding was 16 inches long, and the average length of the three terra-cotta blocks from it is $14\frac{1}{4}$ inches, we find, by a simple rule-of-three sum, that for a block to be a foot long in terra-cotta it must be made in a mould $13\frac{1}{2}$ inches long; or, in other words, that the contraction of the clay is $1\frac{1}{2}$ inches in the foot. Having established this so-called "scale of shrinkage," all that is necessary is to provide for all the drawings a rule on which a length of $13\frac{1}{2}$ inches is divided into twelve parts, each one of which represents an inch; and by this rule all the details for the terra-cotta manufacturer will have to be prepared. For any building in which large quantities of this material have to be used, not only the drawings, but also the models for the work should be made under the immediate superintendence of the architect; and for this purpose a shed should be erected on the site of the works, where accurate plaster models for each kind of block may be made. By this means numerous difficulties and misunderstandings are avoided, and the ultimate cost of the ware is reduced; as, if the manufacturer has to make his own models, at his own risk, he must put on a certain percentage for uncertainty and trouble in fulfilling the wishes of his employers.

We may suppose now that the models prepared as we have described have been received at the manufactory. The first step is to coat them with some material which will admit of the ready withdrawal of the fresh plaster with which they will

have to be encrusted in forming the mould. Nothing could be better for this purpose than clay water, or soft soap and oil; and having brushed them over with one or the other of these preparations, the work of moulding may at once commence.

THE ELECTRIC TELEGRAPH.—X.

By J. M. Wigner, B.A.

BRIGHT'S BELLS — POLARISED MAGNET — CHEMICAL TELEGRAPHS—BAIN'S—BAKEWELL'S COPYING TELEGRAPH—CASELLI'S PAN-TELEGRAPH.

We explained in our last lesson the manner in which an ordinary Morse instrument may often be read by the sound alone, and also the special modification employed in America for this purpose, and known as the "sounder." An acoustic instrument is plainly a great advantage, since, both eyes and hands being free, the message can be easily written down by the receiving clerk.

Attention has therefore been directed to the construction of improved forms of acoustic telegraphs, and Sir Charles Bright has invented an instrument, known after him as "Bright's Bells," which, with various modifications, has been used on several lines. In this two bells are employed, so selected as to produce notes differing by several tones, and thus to be easily distinguishable. A single stroke on the one of these which produces the higher note is taken as the equivalent of a dot in the ordinary Morse alphabet, while a stroke on the other represents the dash. It will thus be seen that only a single sound is required for each sign, instead of two, as is the case in the "sounder." The signs are for this reason much more simple and distinct.

In a circuit where there are two line-wires, an acoustic instrument of a very simple construction may be used. An electro-magnet may be connected with each line-wire, and the hammers which strike the two bells may then be fastened to the keepers of the magnets. A yet simpler plan is to fix the two bells side by side, just space enough being left between them for one hammer to play on both. The keeper of the magnets is then fixed to the rod which supports the hammer, and the magnets are placed one on each side of this rod so as to face one another. As soon as either magnet is excited by the current passing round it, the keeper will be drawn to it, and the bell on that side will be struck. Two small spiral springs keep the hammer in a central position when no current is passing.

The need of two line-wires is, however, a great drawback in this, since it entails much extra expense both for repairs and maintenance. Bright's instrument was accordingly so contrived as to require but one. This was accomplished by means of a "polarised magnet," the principle of which must be carefully understood, as it is often introduced in other pieces of electrical apparatus. In an ordinary electro-magnet the core consists of a piece of soft iron, and is quite devoid of magnetism, except when the current is circulating round it. In the polarised magnet, however, the cores, instead of being fixed to a piece of plain iron, are placed on one end of a permanent magnet, *n s* (Figs. 43 and 44). In this manner a permanent north polarity is imparted to the poles of each core. The keeper *a b* vibrates on a pivot at *a*, which is in communication with the other end of the magnet, and acquires south polarity. It will thus be seen that the keeper has opposite polarity to the poles between which it plays, and is equally attracted by each; it remains therefore at rest midway between them. If now a positive current be transmitted along the line-wire, the slight polarity imparted to the cores by the permanent magnet will be quite overcome, *d* will then become positive, and *c* negative. The keeper will thereupon be attracted by *d*, and at the same time repelled by *c*, so that it will at once move towards the former. If a negative current be sent, the poles will be reversed, and the keeper will be attracted by *c* and repelled by *d*, and accordingly will move in the reverse direction.

The application of this principle to some of the alphabetical telegraphs will be considered in a subsequent paper. The manner in which it is employed in the acoustic telegraph will easily be understood. All that is required is to fix a hammer or tongue to the end of *a b*, and place the bells on each side of this, so that a positive current will cause it to strike one bell, and a negative the other; or we may have an additional magnet to each bell, and call these into play by means of contact-springs placed at each side of *a b*. The two bells may then be a little way apart.

The commutator employed with the single-needle instrument may be employed to transmit the messages to this instrument, since it is so constructed that positive or negative currents at pleasure may be transmitted by it according to the direction in which we incline the handle.

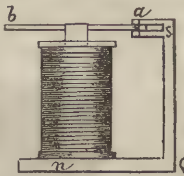


Fig. 43.

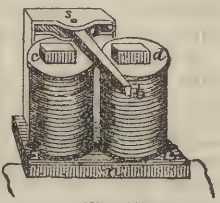


Fig. 44.

We will now turn our attention to those forms of telegraph instruments in which the property possessed by the electric current of decomposing various chemical substances is turned to acccount.

As the student is already aware, very many compounds may be decomposed or separated into their component parts by means of the electric current; some even which resist almost all other agents may in this way be torn asunder. Now if we can choose any substances which will by their decomposition leave a stain on a strip of paper, it is clear we may by means of these transmit intelligible signs along an insulated wire.

A simple experiment will illustrate this principle. Take a sheet of white blotting-paper, and having wetted it well with a solution of iodide of potassium, lay it on a metal plate—as, *e.g.*, a sheet of tin—connected with one pole of a galvanic battery.

Now move the other battery wire about over the surface of the moist paper, and it will be found that a distinct brown mark will be produced wherever the wire has touched. The reason of this is that the iodide of potassium has been decomposed by the electric current, and the iodine which existed in it in a state of combination has been set free and stained the paper. The marks produced in this way are, however, fugitive, since as the paper dries the iodine evaporates, and soon disappears. There are, however, several other solutions which produce permanent marks. That most commonly employed is a solution of ferro-cyanide of potassium and nitrate of ammonia. The paper, which must not be glazed, is cut into strips, and after being wetted with this, is made to pass under a steel point, being carried onwards by rollers as in the Morse instrument. The current then passes through the steel point, and whenever it so passes a blue stain is produced on the paper, the iron of the style or point being slowly dissolved, and combining with the salt of potassium under the influence of the electric current.

In other cases the paper is prepared with starch and iodide of potassium, and in this way too a very clear blue mark is produced. Now we must see in what way this power is made use of in recording a message.

The simplest form of chemical telegraph is that introduced by Bain, and the action of the receiving apparatus will be easily understood by Fig. 45. The line-wire L is connected with the iron style S, which presses against the metallic roller R. This roller is in communication with the earth-plate E.

The strip of prepared paper is drawn onwards towards B by means of the rollers C C, and is thus made to pass steadily along between the point S and the roller R. The message is transmitted by the ordinary key, or by means of a relay, and is thus chemically printed on the strip instead of being embossed or inked.

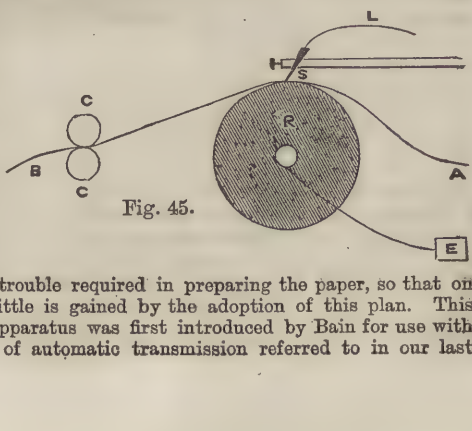


Fig. 45.

The receiving apparatus is thus simplified, but there is much more trouble required in preparing the paper, so that on the whole little is gained by the adoption of this plan. This recording apparatus was first introduced by Bain for use with his system of automatic transmission referred to in our last

paper, and it certainly possesses the advantage of great simplicity of construction in the apparatus. In his original arrangement a disc of prepared paper was employed in place of a strip, and the style was so arranged that it gradually travelled from the centre to the circumference as the disc rotated. Thus the message was traced in a spiral line commencing at the centre, and gradually extending to the circumference.

There are two very remarkable forms of chemical telegraph which we must now explain. In all instruments hitherto described the message has been transmitted in cipher, that is, by means of some arbitrary signs only intelligible to the initiated. In the instruments we are now speaking of the message is received in ordinary written characters, and even the handwriting of the sender is reproduced. It is, in fact, possible to go even further than this, and to transmit a drawing or a portrait by means of these ingenious arrangements.

The operation of these instruments may very easily be understood. In the former of them, which is known after its inventor as Bakewell's Copying Telegraph, two cylinders of the same dimensions are employed, one being placed at each station; these are made to revolve at exactly the same rate. A considerable difficulty was at first experienced in attaining this, but by means of an electro-magnetic regulator Bakewell succeeded in overcoming it. These cylinders are put in electrical communication with the earth at their own stations, and a metallic pointer is placed at one side of each cylinder. This pointer is moved slowly along by means of a long screw, so that for each revolution the cylinder makes the pointer advances about one-twentieth of an inch. The pointers in the two instruments are put in electrical communication with one another by means of the line-wire, the battery being interposed in the circuit.

A sheet of paper prepared in the manner already described is now placed round the cylinder of the receiving apparatus, and it is clear that if a continuous current is allowed to pass a spiral line will be traced from one end of the cylinder to the other, the different lines very nearly touching. When the paper is taken off from the cylinder and unrolled, it will be found to be ruled across with close parallel lines. Any interruption in the current will, of course, cause a break in these lines, and leave a white space; and by duly arranging these spaces, letters or any required marks may be produced. Now a very simple plan was devised by Bakewell for thus interrupting the current so as to produce the required letters. The message to be sent is written with a non-conducting varnish on a sheet of silvered paper or tinfoil the same size as the receiving sheet of paper. When the varnish is dry, this sheet is placed in the cylinder of the transmitting apparatus. The pointer of each instrument is then brought to the end of the cylinder, and both are started. The current passes through the tinfoil, and the pointer which rests on it, then along the line-wire to the distant station, and there it commences to trace its spiral line. As soon, however, as a line written in the varnish comes under the pointer, the current is momentarily interrupted, and a corresponding blank is left in the paper at the other end. In this way every line of the message is faithfully reproduced, and the message appears at the receiving end distinctly written in white letters on a blue ruled ground. Fig. 46 represents the words "Bakewell's" as received by an instrument of this kind.

Fig. 46.

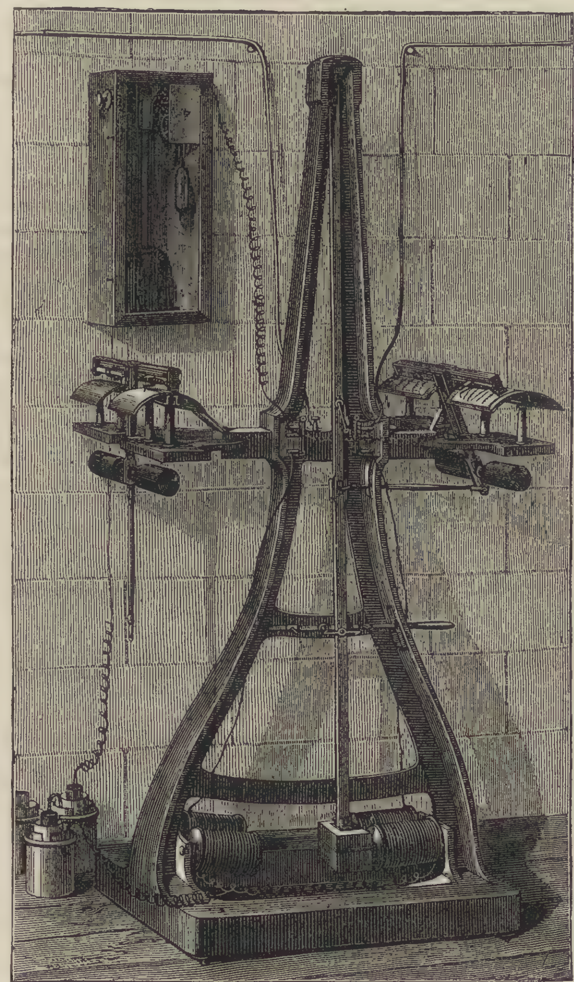


Fig. 47.—CASELLI'S PAN-TELEGRAPH.

If desirable, a relay may be introduced into the circuit so arranged as to reverse the writing, and trace it in blue letters on a white ground. The connections in the relay must in this case be specially arranged, so that when the line-current is passing, the local one is interrupted, and *vice versâ*. There is, however, little need for this alteration, as the message received in the ordinary plan is quite legible. Considerable speed can be attained by this instrument, which is certainly a very remarkable one, but the difficulty of ensuring the synchronous movements of the barrels is a great drawback, and it has not been employed except for experimental purposes, and to illustrate what can be effected by means of the telegraph.

Another instrument of this class was invented by the Abbé Caselli, and was called by him the Pan-telegraph, on account of its power of transmitting in any language, or even, if needs be, in short-hand.

The annexed figure (Fig. 47) shows its construction, and it will at once be apparent that it acts in a very similar way to Bakewell's instrument just described. In place of the cylinders there used, there are here two curved tables fixed to the stand, and on one of these the message is written. The pen, which is mounted so as to travel in an arc, moves from side to side of these, and advances a short distance at each motion. Its movements are controlled by means of a rod connected to the pendulum.

The pendulums at each station are similar in length and weight, and their movements are controlled by the electro-magnets seen at the base, so as further to ensure absolute uniformity of speed. Two tables will be seen at each side of the instrument—those to the left are for transmitting the messages, those to the right for receiving them. The reason of there being two tables is that one is used as the pendulum oscillates from left to right, the other as it returns. Two messages are thus sent simultaneously. Either set may be called into action by connecting the loose rod under them to the centre of the pendulum. In the figure the receiving side is at work, the other rod being disconnected. The alarum is placed above the transmitting apparatus, and the rest of the details of this ingenious form of the electric telegraph may easily be understood from the figure itself.

CIVIL ENGINEERING.—VIII.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DOCKS.

THERE are a variety of important engineering operations which require to be carried on either beneath or contiguous to water. Special plans of action are required for such operations, and we propose to group the whole together under the general title of *marine* engineering. The subject of this paper stands foremost amongst this class of operations, and to no country in the world are they of such importance as to Great Britain; not only on account of the nature and extent of its coasts, but also on account of its gigantic commercial navy. Wherever its fleets of vessels congregate, either for loading or discharging, there of necessity will our most extensive docks be found.

Docks are of two kinds, *wet* and *dry*. In deciding upon the formation of a dock, the nature of the soil must engage the most careful and particular attention of the engineer—not, it may be, with the idea of changing the locality if the soil be unsuitable, but in order to be prepared for every difficulty which may arise in respect of the soil. The area of the proposed dock is a material element in considering the cost, and whilst upon the one hand it is useless to incur unnecessary expense in this respect, it is equally important, upon the other, to prepare for what may arise in consequence of a probable increase in the trade of the port.

The more important features in the construction of a dock are—(1) the *walls*, (2) the *gates*, and (3) the *approaches*. The height of the walls—that is, the depth of the dock—must depend entirely upon the draught of the vessels which can enter at the highest spring-tide; in other words, it must assimilate itself to the natural depth of water *outside* the artificial entrance, so that any vessel capable of approaching the entrance from without, under any circumstances of tide, can be sure of passing over the sill of the gates, and of floating when inside the dock.

The walls of docks require the utmost care in their construction. The soil must undergo a very careful examination by excavation and trial borings, and the foundations be laid at sufficient depths—not less than six or seven feet—below the soil, so as to prevent the possibility of any disturbance of it by the movement of the water, the footings being protected by rows of piles and planking. In some situations it may be necessary to provide for the proper escape of land water, otherwise there is the risk of either its washing away the soil and exposing the foundations, or of its thrusting the entire wall out of its normal position. The best method of doing this is to lead the water by a formed channel, dredged out at a sufficient distance from the wall. The outer and more exposed walls should have considerable slope, which should be increased according to the extent of the exposure; this especially applies to walls exposed to the sea. When dock walls are exposed upon one side to tidal waters with only a small amount of soil intervening, it is necessary that the back face of the wall should be puddled with clay, since the pressure of the enclosed water at low tide has been sometimes known to force itself through the wall and bank.

It seldom occurs that the soil upon which a retaining wall has to be built is sufficiently firm to permit of piles being dispensed with. The whole of the foundations of the Humber Dock wall are piled, the piles being 9 inches square under the main wall, and 8 inches square under the counter-forts, which are 3 feet 9 inches wide. Sleepers of half-timber are bolted down upon the heads of the bearing piles, and the whole covered with four-inch planking. These walls have a perpendicular height of 32 feet, the top receding 6 feet 8 inches from the vertical line. This recession is shown in Fig. 14.

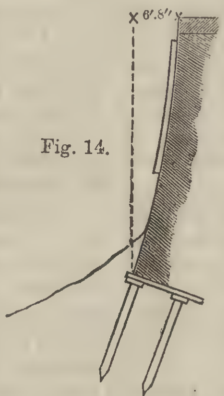


Fig. 14.

The walls are 10 feet thick at the bottom, and 4 feet 6 inches at the top, and are protected by oak fenders 12 inches square.

In all cases of walls constructed in the sea or in deep rivers, the foundations require the greatest care. In constructing the bridge at Neuilly, Perronet laid over the heads of the piles a piece of whole timber, and filled it up level with rubble; another series of timbers of the same scantling was laid in a transverse direction, and again brought level by another filling-up of rubble, and the wall built upon it. Similar precautions were adopted for the walls of the docks at Rochelle, which were faced with freestone and backed in with brick, whilst a row of sheet-piling was driven along the whole length of the footing, to prevent the water from acting upon the foundation. There are various methods of attaching the upright fenders to the walls of docks; one very secure plan is to attach them by spikes and angle-irons to T-irons set in the solid masonry.

Instances occur, as at Brunswick Wharf, Blackwall, in which the wall facing the water is constructed wholly of iron. The mode of procedure was as follows:—A trench six feet in depth was dug along the intended line, and timber piles driven therein. The iron piles may be in one or more lengths. If the latter, as was the case at Blackwall, they are fastened together by a socket-joint and screw-bolt. They are usually driven at intervals of about seven feet, and the intermediate spaces filled in with sheeting-piles, which are secured at the top by two bolts to the top wall of the wood-work at the back. The iron plates which fill up the spaces over the sheet-piles were bolted to the main piles and to each other, and the joints stopped with iron cement. At Brunswick Wharf the work is backed by a wall of concrete, and has a granite coping. Upwards of 900 tons of iron were employed in the construction of this wharf, which is 720 feet long.

The gates of docks are in principle the same as those already described in connection with canals, but being as a rule very much larger, they differ in points of detail. They are not unfrequently constructed of iron. In all large gates it is usual to rest the foot of the gate upon a curved traverse plate of iron, by a wheel running on centres fixed to the gate itself, the iron traverse being bedded level into the stone apron.

The balance lever is also dispensed with, and the gates opened and shut by chains running through holes cut in the masonry of the side walls, and passing over friction rollers up to a windlass. The chain may be endless, care being taken to obtain sufficient grip on it, by passing it a number of times round the barrel of the windlass. A fine pair of iron gates are to be seen at the wet dock at Montrose. The entrance to the dock has a width of 55 feet in the clear, the centre of the heel-post being recessed 12 inches within the face of the wall; thus each gate is 28 feet 6 inches wide, and 22 feet 6 inches high. When closed, the line of shutting is 10 feet from the straight line which joins the centres of the heel-posts. These latter are 21 inches in diameter, and in section a little more than a semicircle; they were turned in a lathe after casting. Their thickness is $1\frac{1}{4}$ inch, and they are made to fit into a cast-iron socket, and work on an iron gudgeon 10 inches in diameter, cast on a plate 4 feet 6 inches long, 21 inches wide, and 2 inches thick. This plate is dovetailed and riveted firmly into the stone, and keyed so as to press the curved side of the heel-post into the quoin. The quoins are cut to the same curve as the heel-posts and are polished, and the contact between the stone and metal surfaces is so close, that scarcely any water is able to pass between. The mitre-posts are 18 inches broad, and $1\frac{1}{2}$ inch thick. They are cast with holes to receive the iron bars, which are eleven in number, 2 inches thick, 16 inches broad at the ends, and 18 inches in the middle. Across their ends are 2-inch plates with $4\frac{1}{2}$-inch screw-bolts, two bolts to each bar, which pass through the heel and mitre posts. The sills against which the gates close are of iron, cast in four pieces 8 inches deep. The bottom rail of the gates is of oak, fixed to the lowest iron rail by $1\frac{1}{4}$-inch bolts, and bedded to it by a layer of felt. The oak rail is 12 inches thick, 17 inches broad at the ends, and 19 inches in the middle. The gates have a double lining of boiler-plate, the plates overlapping each other $2\frac{1}{2}$ inches. They are $\frac{3}{8}$-inch thick for the first 6 feet from the bottom, and $\frac{5}{16}$-inch thick above. The collars supporting the heel-posts are of wrought iron, 4 inches deep and 2 inches thick, keyed through the anchors; these are of cast iron $3\frac{1}{2}$ inches square, dovetailed into the quoins and run with lead.

The curved traverse plates are 10 inches broad and 4 inches thick, sunk into the stone and bolted, and bedded with felt and white lead. The rollers upon which the gates rest are of cast iron, 18 inches in diameter and 5 inches thick, running upon steel axles. The roller-boxes are of cast iron $1\frac{1}{4}$ inch thick, and fastened by screw-bolts through the sides of the lowest rail. The sluices are 3 feet by 2 feet, and the sluice-valves are $1\frac{1}{4}$ inch thick. The rods for raising and lowering the valves are 2 inches diameter, terminating at top in a square-threaded screw with brass nut, worked by a wheel and pinion and crank handle. The chains for opening and closing the gates are $\frac{7}{8}$-inch, proofed to a strain of 22,000 lb. The entire weight of each gate is about 53 tons, and when closed and the water away from the concave side, they conjointly support a water-pressure of about 384 tons.

The entrances to docks are sometimes closed by means of pontoons, which are large hollow vessels fitted with a kind of keel or projection round the sides and bottom. This keel corresponds with and fits into a recess cut in the stone-work of the entrance. The water being withdrawn from the pontoon by pumps attached to it, it can be floated over the recess, and if then gradually filled with water, it will settle down into it and effectually close the entrance. Pontoons are constructed either of timber, copper, or iron. There is only one objection to their use, which is the necessity for their being floated entirely away when a vessel requires to pass the entrance; in other respects they have an advantage over gates, both in simplicity of construction, and freedom from the wear to which large gates are subjected. They may therefore be employed with advantage in closing dry docks, which do not require to be frequently opened and shut.

It would be useless to enumerate all the very excellent docks which this country possesses, but some of the more important deserve a short notice, possessing as they do points both of interest and instruction. First in importance are the many extensive docks and basins situated upon the banks of the Thames, and communicating with the river.

The London Docks, completed in 1805, were amongst the first opened. These splendid works were executed under the supervision of Mr. Rennie, and occupied five years in construction. They have two entrances, one at Wapping, and another higher up the river at Hermitage. The entire area within the boundary walls is about 71 acres, of which 27 acres are water. A vast amount of water percolated into the excavations, requiring the constant use of an engine of 20 horse-power to keep it under.

The East India Docks, the works of which were executed under the direction of Mr. Rennie, consist of two docks, the export and import, and a basin, having an area respectively of 10, 19, and 3 acres, with a depth of water of about 26 feet.

The West India Docks consist of two docks and two basins. The docks lie parallel with each other, and are 890 yards long, the larger being 500 feet broad, and the smaller 400 feet broad, and contain respectively 30 and 25 acres. The basins form connections between the river Thames and the extremities of the docks, and are respectively 2 and 6 acres in extent. The water in the basins is nearly the same level with that in the docks, and the length of time the water remains in them before passing into the docks, enables the sediment to be deposited in them.

The St. Katherine's Docks were constructed under the direction of Mr. Telford, in 1828. Although not so extensive as some of the others upon the Thames, they are yet very complete in their arrangements. The lock by which they communicate with the river is 45 feet wide, and 180 feet long. There is a depth of water over the sills of 28 feet at spring-tides, and of 10 feet at low springs. The water-area of the docks, basin, and entrance is 11 acres. The water is readily maintained at the same level in the docks and basin, by means of two steam-pumps of 80 horse-power each, which draw their supply from the river. The soil upon which the walls of these docks are built is a hard gravel, which being pervious to water, it was necessary to line the whole of the bottoms of the docks, and the foundations of the walls and counter-forts with impervious cement, and to puddle the backs of the walls with clay. The concrete upon which the walls stand is composed of eight parts of coarse sand and one of blue lias lime, and was laid on 12 inches in thickness. A sill of wood was laid under the front edge of the wall, and protected by a row of sheeting-piles 14 feet long and 9 inches thick, driven close and having their joints caulked for 3 feet in depth. The entrance lock is built of grey stock bricks, laid in mortar made with lias lime, and the platforms, copings, and hollow quoins of Bramley Fall stone laid in cement.

Whenever practicable, it is advisable to keep a harbour free from mud by sluicing. Hartlepool affords a good example of this system. The channel for conveying the scouring water is a tunnel 15 feet wide and 4 feet high, between the springing of the top arch and invert. The thickness of the side walls is $5\frac{1}{2}$ feet, protected by external buttresses $3\frac{1}{2}$ feet thick, and 4 feet projection. The tunnel throughout is floored with 3-inch plank. The sluice-gates or paddles are of cast iron, and work in cast-iron frames.

The retaining walls of the Hartlepool Docks have a curved face, being 12 feet wide at the base, and 6 feet at the top. The curve represents an arc of a circle, having a radius of 80 feet.

The most magnificent and extended range of docks in the world is situated at Liverpool, upon the north bank of the Mersey. Upwards of thirteen spacious docks are collected at this port, exclusive of basins; of which eight are connected together by locks, whilst another group of four lie to the east of the others, these also being connected together by locks. There are altogether nine separate entrances from the river. The first dock was constructed here in the reign of Queen Anne, and is called the Old Dock; and the others have followed in rapid succession, so great has been the increase in the shipping of this port, and the consequent demand for dock accommodation. The Old Dock measures 198 yards by 85 yards, and is one of the smallest of the whole. Another, the West India Dock, measures 867 yards by 170 yards, and is 29 feet deep; this alone will hold nearly 300 ships. The several docks are connected by scouring tunnels and sluice-gates. The operation of sluicing is exceedingly effective and simple. A dock about to be cleaned is left dry at low water by closing the gates, and the various sluice-gates being opened, a number of men with shovels enter the dock, and throw the accumulated mud into the channels formed by the sluices, which carry it out into the river. The spring-tides rise to a height of 33 feet at Liverpool, and at this period there is a depth of 89 feet in the channel of the Mersey opposite the docks. The quays alongside the docks are very extensive and well constructed, and to facilitate the shipment and unshipment of goods, a continuous line of rails is carried along the north side of the docks from east to west, and connected with the great railway system of the country by branch lines. A complete system of telegraphic communication also exists between the various docks and the Custom House.

Very extensive docks exist at Bristol. A company was formed in 1804 for constructing docks at this port. They cover 82 acres of ground, and extend along the banks of the river Avon for $2\frac{1}{2}$ miles. The engineer, Jessop, subsequently diverted the river for a length of two miles, and cut a canal to carry off the water. The channel thus drained was converted into a splendid floating dock of 70 acres area, having an entrance basin opening by double locks into the Avon below, and by a single lock into the old channel above.

SEATS OF INDUSTRY.—XIII.

BRADFORD.

BY WILLIAM WATT WEBSTER.

ABOUT eight and a half miles to the west of Leeds, and thirty-four miles to the south-west of the city of York, stands Bradford, the chief centre of the worsted manufactures of England, and the principal mart for the long wools used in worsted fabrics. The site on which the town is built is exceedingly healthy, as is proved by the low annual rate of mortality; and the surrounding district is very fertile, and yields an abundant supply of coal and iron. From the circumstance of Roman coins having been found in the refuse of an ancient bloomary in the neighbourhood, it is believed that the iron mines were worked by the Romans during their occupation of the island. But before the Norman conquest nothing is known respecting Bradford except that it formed part of the parish of Dewsbury, and its earlier history is entirely associated with the castle of

the Laceys, Lords of Pontefract, which was erected there shortly after that event.

The loosely spun woollen yarn called worsted received its name from the little town of Worsted in Norfolk, where it was manufactured as early as, and probably before, the time of Edward II. At what date this industry was first introduced into Bradford cannot be ascertained. In the Act 33 Henry VIII. c. 16, worsted yarn is described as "the private commodity of the city of Norwich;" while the Act 34 and 35 c. 10 of the same monarch, after declaring "that the city of York afore this time had been upholden principally by making and weaving of coverlets, and the poor thereof daily set on work in spinning, carding, dyeing, weaving, etc.," and that the manufacture having spread into other parts was "thereby debased and discredited," enacted that henceforth "none shall make coverlets but the inhabitants of the city of York." At this time Bradford almost rivalled Leeds as a woollen cloth-making centre, but both towns were surpassed by Wakefield, and worsted-making was one of the special occupations of the inhabitants of Bradford, although Norwich was then the chief centre of the manufacture. Owing to the settlement of Flemish artisans in Norwich, in the reign of Queen Elizabeth, and the improvements they introduced, the worsted trade of Bradford declined during the seventeenth century, but throughout the greater part of the eighteenth century it was gradually returning, in consequence, it is said, of the extravagant wages demanded by the workmen of Norwich, which drove the masters to the cheaper labour market of Yorkshire. However, in 1800 the population of Bradford only numbered 6,400.

The only events of any great political importance connected with Bradford took place during the Civil Wars, when the inhabitants espoused the cause of the Parliament, and twice defeated the Royalists, but were themselves afterwards defeated by a force under the command of the Earl of Newcastle. With these exceptions the history of the town is wholly industrial, and the period of greatest interest is the last eighty years. Bradford has increased and prospered as machinery has been more and more applied to the branches of manufacture cultivated in the district; but it was with the greatest difficulty that this advance was made, owing, in the first instance, to the opposition of the townspeople generally, including the manufacturers, and, in later instances, to the opposition of the operatives. In 1793, a Bradford manufacturer named Buckley wished to erect a mill to be driven by steam-power, but desisted in consequence of being threatened by his neighbours with a prosecution for nuisance. In the following year the first spinning machinery of Crompton's make was started by James Garnett, the founder of one of the largest manufactories in the kingdom, and within ten years after several thousands of spinning machines were in operation in the town. The extension of machinery placed the workpeople at a disadvantage for a time, and, under the mistaken impression that their condition would be permanently injured, they resolved on the destruction of the novel inventions. A great riot took place in 1812, which was quelled by the military and the police, and seventeen "Luddites," as the rioters were called, were condemned to death and executed. But the machinery went on increasing, notwithstanding the antipathy of the workers, and by 1815 there were ten mills in Bradford, with an aggregate of 256 horse-power. In 1825 the number of mills was twenty-six, and the horse-power had risen to 706. The workmen, however, were not yet reconciled to the change in the system of manufacture, and in this year 20,000 persons engaged in a strike for increased wages, which lasted six months, and caused wide-spread suffering. In 1826 another organised attempt was made to check the spread of the obnoxious machinery by force. A riot, specially directed against the worsted power-looms that had been recently introduced, broke forth, in the course of which two of the rioters were shot dead, and several severely wounded, by the defenders of the factories. After this occurrence the opposition to machinery seems to have gradually subsided, and in 1835 there were in Bradford 73 mills, with a steam-power equal to 1,647 horse. Fifteen years ago the worsted factories in Great Britain numbered 525, and gave employment to 87,794 persons, and no fewer than 186 of these factories, employing 30,517 persons, were situated in the town and neighbourhood of Bradford. Since then very marked progress has been made. Within the past few years many merchants from Leeds and Manchester have established their head-quarters at Bradford, and the town has been greatly improved in many respects and considerably extended.

The population of the town and parliamentary borough of Bradford has steadily increased throughout the present century. In 1821 Bradford contained 13,064 inhabitants; in 1831, 23,233; in 1841, 34,560; and in 1861, 48,646. The townships of Manningham, Bowling, and Horton, and the villages of Great and Little Horton, are included within the Parliamentary boundary, which in 1841 comprised 66,508 inhabitants, and in 1861, 106,218. The Reform Bill of 1832 gave two representatives to Bradford, and the date of incorporation is 1847. The town is built of free-stone, and partly on the side of a steep hill, some of the streets overlooking the houses in the lower parts. The streets in the older quarters are narrow, but those more recently constructed are broad, well-paved thoroughfares, and constitute the larger portion of the town. Bradford enjoys facilities of communication with the ports on the east and west coasts by means of the Leeds and Liverpool Canal, a branch of which has been brought into the very centre of the town.

Besides worsted stuffs, mixed worsted, alpaca, and mohair goods are manufactured on an extensive scale at Bradford. Cotton and silk fabrics also form important branches of industry in the town, and the spinning of worsted yarn, to be woven in the power-loom factories, and for export, employs a large number of persons. Broad and narrow cloths, wool-cards, and horn combs are also made in large quantities in the town and neighbourhood, and the dye-works are very extensive. The Low-moor Iron Works, three miles south-east from Bradford, and the Bowling Iron Works, one mile to the eastward of the town, are large establishments, celebrated for the quality of the iron they produce; but this manufacture, although considerable, is not so extensive as might have been expected. But the most famous and the largest manufacturing concern in the vicinity of Bradford is the Saltaire Alpaca and Mohair Works, situated on the Aire, at a distance of about three miles, and which form, with the residences of the workmen and others employed in the works, a flourishing town which is fast rising into importance.

About the year 1834, Mr. (now Sir) Titus Salt, a young farmer, and the son of a Leeds wool-stapler, settled in Bradford as a spinner, and shortly after began to make experiments with a parcel of alpaca wool that had been sent to this country from Peru many years previous to that date, and had been laid aside in a Liverpool warehouse as useless, unworkable material. In 1835 Mr. Salt bought 300 bags of the "South American stuff," at eight-pence per pound, and set to work to manufacture it. By 1853 upwards of 2,000,000 pounds of alpaca wool, the greater part consigned to Mr. Salt, had been imported into England, and in that year he built the Saltaire Mills and the adjoining town, which is capable of accommodating 5,000 persons. Upwards of 4,000 workpeople are employed in the Saltaire establishment, which covers six acres of ground. The town itself, with its various institutions for the health, recreation, and instruction of the inhabitants, may be regarded as one of the best models of a well-regulated industrial community that we possess.

Bradford contains a free grammar school, founded in the reign of Edward VI., and chartered and partly endowed by Charles II., which was rebuilt in 1830. This school is open to all boys belonging to the parish, who may become candidates for an exhibition in Queen's College, Oxford. On the outskirts of Bradford is Airedale College, an institution for the preparation of young men for the Independent ministry, and at Little Horton the Baptists have a similar academy. At Woodhouse Grove the Wesleyan Methodists have a school for ministers' sons, and at Fulneck, five miles to the east of Bradford, there is a Moravian settlement. Among the public buildings the most prominent and noteworthy are the Piece Hall, built in 1773, and used for the exhibition and sale of alpaca and other stuffs; the Court House, built in 1834; and St. George's Hall, an edifice in the Corinthian order of architecture, erected in 1853 at a cost of £28,000, and capable of accommodating 3,350 persons. Bradford has also a fine public park. There are three important annual fairs held at Bradford, and the wool sales are attended by buyers from the most distant parts of the country. Every seventh year a festival in honour of Bishop Blaise, the reputed inventor of wool-combing, is celebrated in the town with great gaiety.

WEAPONS OF WAR.—X.

BY AN OFFICER OF THE ROYAL ARTILLERY.

ARTILLERY CARRIAGES.

Having already given an account of the various natures of guns which the present state of artillery science recognises as best adapted for offensive and defensive purposes, we proceed to consider the mechanical appliances external to the gun itself, which are designed to complete its efficiency as a tool in the soldier's hand. All such appliances are embodied in the gun carriage, its furniture and accompaniments. These in the field artillery would include the limber, ammunition wagon, and other vehicles; and, in the garrison or naval artillery, the platform or slide on which the carriage is worked.

Too much importance cannot be attached to the object of perfecting the carriage with its equipment. Indeed, it is impossible to overrate its value. Upon the completeness of the carriage the gun depends for the due development of its destructive power. We may accept it then as an axiom, that the carriage complete should be so constructed as to qualify the gun effectually to cover with its fire the most extended area of country in the shortest period of time which the surrounding conditions and the highest attainable mechanical skill will render possible. It will be readily understood how large a field of experimental research must have been explored in seeking a satisfactory realisation of these requirements.

To adopt a simple method of classification, all artillery carriages may be included under one of two heads, according as they are intended for "field" or "garrison" service. These two chief denominations divide themselves into several subordinate varieties, such as carriages for mountain warfare, for guns of position, and siege artillery—the two first of which are closely allied, as regards general construction, to field artillery carriages proper; and in the third we find some natures assimilating to field, and others to garrison carriages.

The broadside and turret carriages of the Royal Navy, too, in their general features resemble some natures belonging to garrison artillery; though in the former mechanical skill has been necessarily exerted to a greater extent than in the latter, with a view to ensuring, under the more difficult conditions of ship-board, an equally perfect control over the guns with that which is obtained on land.

Without entering too minutely into manufacturing details, it is proposed to review the general principles which must be followed in the construction of the two classes of carriages above mentioned, showing also how in obedience to these principles the present forms have come to be adopted.

CARRIAGES FOR FIELD ARTILLERY.

The principal conditions to be fulfilled in a field artillery carriage are—

1. That it shall furnish a convenient and secure support to the gun, both when in action and when travelling.
2. That it be of a form easily handled and manageable, to give direction to the gun when in action.
3. That it be adapted for rapid movements, in conveying the gun not only over good roads, but also over rough and broken country.
4. That provision be made for an ample supply of ammunition and stores, easily accessible to the men serving the gun; also that provision be made for the conveyance, when necessary, of a proportion of these men.
5. That its construction shall be sufficiently strong and durable to resist the statical and dynamical strains and varieties of climatic action to which the contingencies of warfare may expose it.
6. That it shall admit of being readily taken to pieces and conveniently stowed on board ship, a condition which is peculiar to the military carriages of our country.

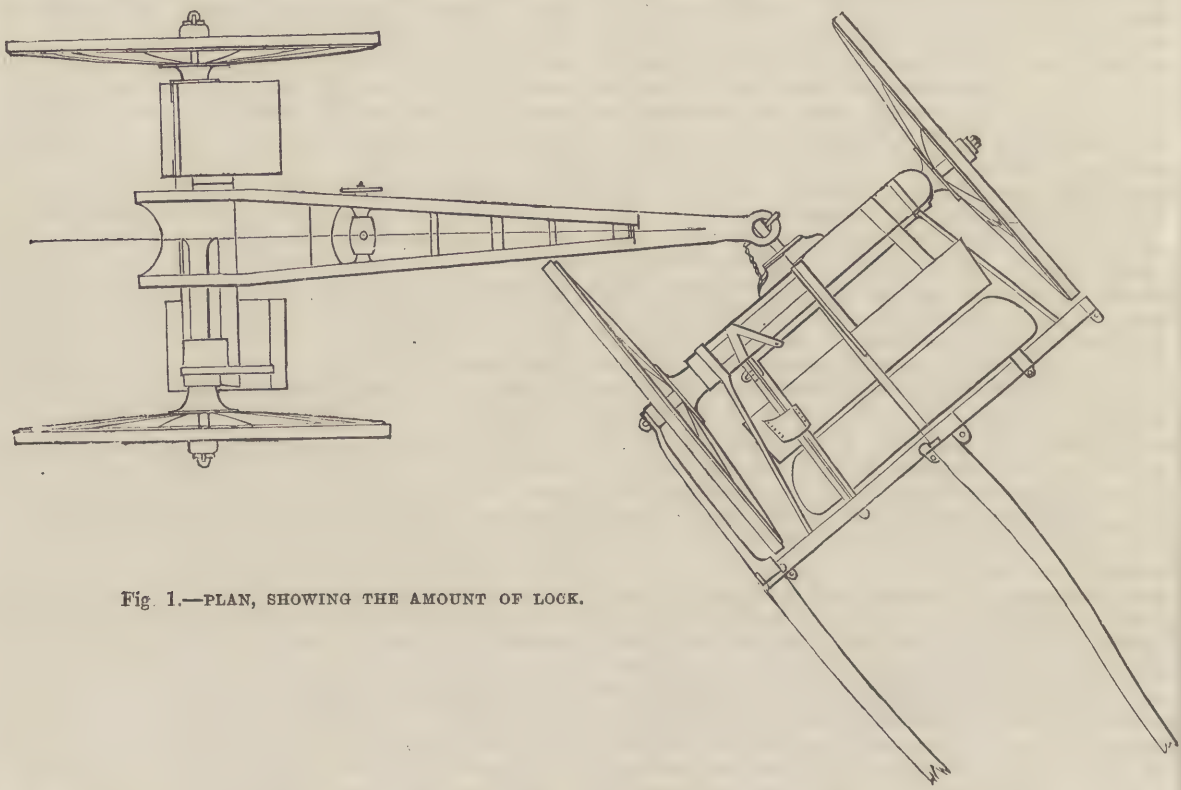


Fig. 1.—PLAN, SHOWING THE AMOUNT OF LOCK.

With respect to the first condition, as field guns have trunnions, a very simple form of carriage can be adopted; all that is needful, so far as the connection between the gun and its carriage is concerned, being a frame supporting the trunnions in such a manner as to allow the gun freedom to rotate about their axis through a sufficient angle for any elevation or depression that may be necessary in laying it. This is secured by providing semi-circular trunnion-holes on the upper surfaces of two cheeks or "brackets," which are separated above from

each other at such a distance as will just allow of the gun working freely between them through certain prescribed angles, and rigidly connected beneath either by cross-pieces termed "transoms," or by a solid block called the "trail," of which more will be said presently. It is highly important that the gun should be elevated and depressed in a vertical plane, this condition being essential to accuracy of fire at long ranges; the common axis, therefore, of the trunnion-holes must be horizontal when the carriage stands upon even ground.

The third and only remaining point of connection between the gun and its carriage is at the cascabel, where there is an appliance for elevating and depressing the gun with great nicety, at pleasure. The more modern designs of field-guns having little or no preponderance, there is but little strain thrown on the elevating arrangement either in travelling or firing, as compared with that which the trunnions exert upon the brackets. As respects the stability of the carriage, it is evident that it must have at least three points of support for standing securely on the ground. Two of these are at once supplied by the wheels on which the carriage travels, and the most suitable position for a third remains to be determined. On firing the gun, a violent shock or impulse is communicated to its carriage in a direction exactly opposite to that in which the shot travels. The third point of support then must necessarily be behind the gun, and so situated as to check any tendency in the carriage either to turn round to the right or left, or to turn over backwards at the moment of firing. To answer the first of these requirements, the point must be selected in the same vertical plane in which the axis of the bore lies, and for the second it must not be within a certain distance from the trunnion of the gun, this distance being fixed by the angle which an imaginary straight line perpendicular to the axis of the trunnions, and connecting it with the third point of support, makes with the ground-plane. This angle, it is found, should not exceed 21°. If the rear point of support were brought nearer to the trunnions the angle would increase, and with it the tendency of the carriage to capsize backwards on firing. This angle is in effect the limiting angle of friction for field-gun carriages. The rear point, then, is well behind the gun; its connection with the body of the carriage is secured by a substantial beam called the "trail," which is strongly joined to the axletree in front, and rests on the ground behind. All that is needed for the stability of the gun and carriage, when the latter stands ready for firing, is that the vertical line passing through their centre of gravity should fall within the triangle formed by their three points of support. In practice it is found that if the gun is balanced just over the axletree, so that the axes of both trunnions and axletree are nearly in the same vertical plane, the conditions of stability

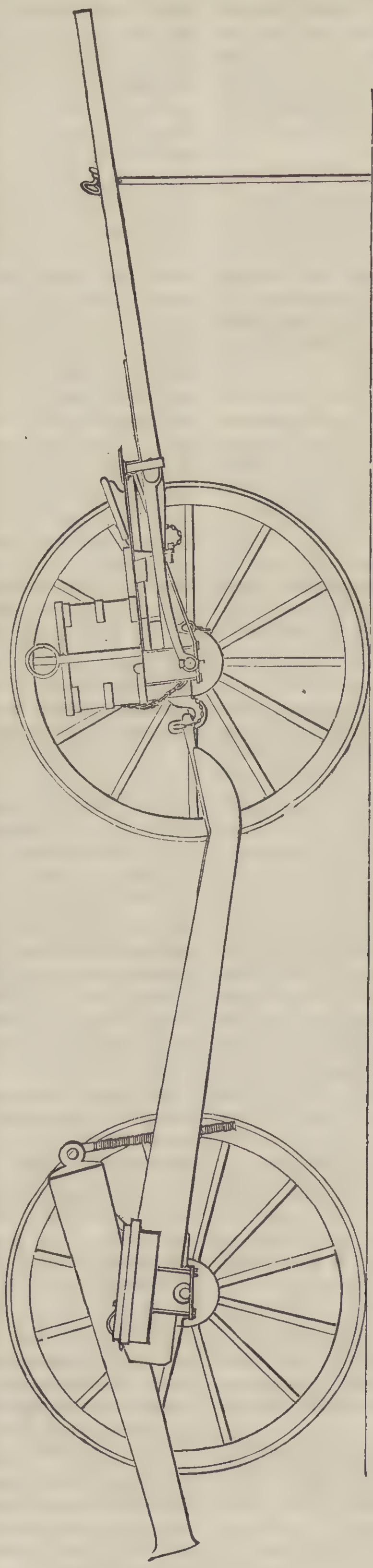


Fig. 2.—FIELD-CARRIAGE, "LIMBERED UP."

are secured. By this arrangement the pressure of the rear end of the trail on the ground is about one-half of its own weight.

So far, then, as respects the stability of the gun and carriage, both when firing and when ready for firing, the conditions are realised in a two-wheeled carriage provided with a trail of suitable dimensions. The next question for consideration is, how would such a carriage travel? It will be at once evident that, excepting for very light guns, a carriage such as now described on two wheels only would be inadmissible, for this reason—the pressure exerted by the trail on the ground when in the firing position, would when travelling have to be sustained by the horse; and in the ordinary descriptions of field-carriages the weight and unwieldiness of the trail alone would be a serious objection to such a method of draught, and the means of attaching and detaching the horses would be correspondingly clumsy. We conclude, then, that a gun-carriage provided merely with two wheels and a trail body, while exhibiting an excellent combination for firing purposes, is altogether ill adapted for travelling, excepting when applied to very light artillery such as that designed for mountain service. Here a proportionally light carriage is needed, to the trail of which a pair of shafts can be readily attached, their combined weight being supported with ease by the draught animal, which is generally a mule.

In the field artillery, therefore, an additional pair of wheels for the support of the end of the trail becomes necessary when travelling, and the result is a four-wheeled carriage. It so happens that the construction we have seen to be very suitable as a standing carriage, offers great facilities for being converted at will into a simple and efficient form of travelling carriage. All that is needed for this purpose is to procure an independent fore-carriage to which the horses are harnessed. Attached to the centre of the hind part of this carriage is a strong hook. To the end of the trail of the gun-carriage proper must be fitted a suitable iron loop. This is known as the "trail eye." Lifting the end of the trail off the ground to a height just above the level of the hook on the fore-carriage, the hook is brought under the trail eye, which is then lowered down into it, and secured by a horizontal key which passes through the end of the hook. We are thus provided with a strong and well-constructed four-wheeled carriage. The fore-carriage is known as the "limber;" the process of connecting the trail with it is called "limbering up" (Fig. 2), the converse of which is "unlimbering." The limber, whether attached to the gun-carriage or acting independently, is equally available for movement. In one case it acts as a fore-carriage, in the other as a cart, so far as the arrangements for travelling are concerned. The shafts, which are rigidly connected with the body of the limber, take a share with the wheels in supporting its weight and maintaining it in the

proper travelling position. When the carriage is unlimbered, the weight on the shafts is rather excessive, but this is counteracted when in the travelling position by the weight of the trail acting on the hind part of the limber, and thus counterbalancing the otherwise great preponderance on the shafts, which would act injuriously on the shaft-horse. It is not contemplated that the limber should be required to travel far when detached from its gun-carriage. The undue weight on its shafts when thus detached is therefore a matter of little moment.

We have seen that in order to secure stability in the firing position a certain length of trail is indispensable, and that the entire weight of gun and carriage must be so distributed as to bring upon the point of the trail about half its own weight. As the trail must be lifted by hand for the purposes of limbering up and unlimbering, the weight to be raised should be restricted within the lowest limits compatible with the requirements of stability and strength; its length should therefore not exceed these limits, and its weight must be no greater than what is necessary to ensure sufficient strength to resist the shocks incurred in travelling and firing. In the construction of every kind of vehicle, the minimum of weight consistent with a necessary reserve of strength is the object desired. These properties, lightness and strength, are primarily antagonistic; and the form adopted is in effect that to which science and experience point as being the most effective compromise between them. Again, the length of the trail must be sufficient, and only sufficient, to admit of a free passage between the wheels, in order to gain access to the trail-eye and limber-hook. The space between the front and hind wheels is, of course, dependent upon the length of the trail. It is essential also that the carriage should be short, both on account of covering as little ground as possible when turning, and in order to diminish as far as practicable the length of a column when marching along the road.

Regarded on its merits as a four-wheeled vehicle, one point is especially worthy of notice in the field-carriage. The form of the gun and its particular functions admit of the trail being made extremely narrow, assimilating to the perch of an ordinary carriage. This construction, without sacrificing the advantages secured by a high front wheel, affords ample facility for changing direction. The limber can be turned to the right or left, about the trail-eye, as a centre, through a considerable angle before its wheel comes in contact with the trail, as in Fig. 1. Thus it will be seen that this form of carriage claims for itself almost exclusively the following advantageous combination :—1. A low body. 2. Good locking power. 3. High front wheels. This combination secures pre-eminently the all-important qualities of stability when travelling, and handiness in turning; also a further advantage, which will be presently considered as fulfilling in a great measure the third essential condition which was stated in the onset—namely, the capability of rapid movement.

With reference to the second condition, requiring that the gun should be handy when in action, the two points to be considered are—(1) facility for turning the gun horizontally; (2) in a vertical direction. 1. To turn the gun horizontally, to the right or left, there is an iron staple or shoe fixed upon the end of the trail just above where it rests on the ground. Into this shoe a handspike, which is always carried with the carriage, is stepped, and is so curved that its point or handle shall be raised to a convenient height for a man to take hold of when standing by it. One man is able with tolerable ease to lift the weight of the trail sufficiently off the ground to enable him to move it either to the right or left, causing the gun to turn horizontally about an imaginary vertical axis, equidistant between the wheels, thus giving any horizontal direction that may be required. 2. The vertical direction, or elevation, is obtained by raising or depressing the cascabel. This is effected by an elevating screw, the upper end of which is attached to it, and which works in a female screw below, made to revolve by means of a small handwheel worked on the right bracket of the trail. The gearing is so constructed that a very slight effort with one hand suffices to raise or lower the gun.

With regard to the third condition—namely, the adaptability of the carriage to rapid movement—it has already been observed that high wheels can be used: we will now proceed to illustrate the advantages which they confer. High wheels, if not very ponderous, contribute greatly towards easing the draught. This they do in a twofold manner, first by diminishing friction, and secondly by spanning ruts and hollows on the surface of the road in such a way as to offer less resistance than smaller wheels would offer to the progress of the vehicle. It has been proved by experiment, and is capable of mathematical demonstration, that the traction or pull of the trace is diminished by increasing the height of the wheel. The ease with which horses can draw a carriage increases *with*, though not *as*, the radius of the wheels. If, for instance, a horse harnessed to a cart with wheels of fifteen inches radius draws the load with a pull on the trace amounting to twenty pounds, the pull on the trace would not be halved by doubling the height of the wheels—giving them a radius of thirty inches—but it would be very materially diminished. On ordinary roads, where a succession of trifling obstacles are encountered and surmounted by the wheels, the pull of the trace would be reduced probably from twenty pounds to thirteen pounds by doubling the height of the wheels. Hence, though the advantage to the draught is not directly proportional to the height of the wheels, it is nevertheless very greatly dependent upon their height; and thus it is highly important to maintain the wheels of field artillery carriages at the greatest diameter which the limits of convenience and moderation in weight will permit. The experience of the British artillery has given a sanction to five feet as being the most suitable height of wheel for the artillery service; and with this height of wheel the limber can lock round through an angle of about 52°, giving the carriage abundant facility for turning on ordinary roads, and in manœuvring on the field. This advantageous combination of a high front wheel with a good lock is simply due to the narrowness of the trail, which when the gun is limbered up may be said to take the place of the body of an ordinary wagon

If we turn for an instant to the construction of ordinary wagons, the difficulties involved in securing this combination will perhaps be more readily seen. Nearly every wagon used on ordinary roads at the present day is furnished with front wheels which pass freely under the body—a standing acknowledgment of the importance of good locking power. In order to secure this, however, whilst maintaining a tolerably low position of the body, the front wheel must also necessarily be low to pass under it, very much lower than the hind wheels, the position of which relatively to the body never alters. Now, on the excellent macadamised roads of England, a low front wheel, though objectionable, is not of so very much importance, especially when the wagon is on springs. The first two points of the combination before mentioned are secured; the third is sacrificed. Experience has proved this arrangement to be the best suited for ordinary traffic on good roads. For military service, however, the circumstances are widely different. The carriages accompanying an army in the field must often follow the worst of roads, and not unfrequently across country. Every contrivance, therefore, by which the draught can be lessened must be carefully studied. It is accordingly highly fortunate that the peculiar construction of the gun-carriage does not necessitate a low limber-wheel.

The fourth essential condition is secured by carrying thirty rounds of ammunition complete in two boxes, which are placed on the limber. In addition to these four rounds of case-shot are carried, in two small boxes, on the axletree of the gun-carriage. Each gun is accompanied on service by an ammunition wagon, consisting of a "body" and a limber, which latter is identical and interchangeable with the limber of the gun-carriage. The wagon-body has a perch made of girder-iron riveted securely to the axletree-bed. This perch occupies the place of the trail in the gun-carriage, and, like it, is attached by an eye to the limber-hook. The wagon-body has four ammunition boxes, and its limber two, each containing fifteen rounds of ammunition, making in all ninety rounds. Thus each gun-carriage, accompanied by one wagon, has a supply of 124 rounds of ammunition. This quantity is considered ample for immediate wants, reserves being always in readiness to replenish the wagons as they become exhausted. The limber-boxes are fitted as seats for the conveyance of two, or possibly three men on each limber. In the horse-artillery the remaining members of the detachment serving the gun are mounted. In the field-artillery they march on foot except on emergencies, when two additional gunners sit on the axletree-boxes of the gun-carriage, and others can be mounted on the off-lead and centre horses drawing the gun.

With reference to the fifth condition, it will suffice to say that the dimensions of the various parts of the gun-carriage have been arrived at through the experience of actual warfare, combined with careful calculation. Excepting in the spokes and felloes of the wheels, and the axletree-beds, foot-boards, and bottom-boards, no timber takes any part in the construction.

In the gun-carriage the brackets of the trail are made of plate iron, with angle-iron framing. The body of the limber, excepting the axletree-bed, is also of wrought iron. By a judicious disposal of the iron, the requisite strength is secured without excess in weight. The weight of the 9-pounder gun-carriage and limber packed complete is about 35 cwt. As to durability, it may be affirmed that, with attention to prevent rusting, the carriages and wagons are in all their main parts practically indestructible.

With respect to the sixth and last condition—namely, that of packing on board ship—the ammunition boxes are readily removed; and when the carriages, limbers, and wagons are dismounted from their wheels, an entire battery can be stowed away in very little space, considering the large quantity of stores it includes.

Reverting to the fourth condition, it may be as well to state that every convenience for carrying side-arms, intrenching tools, and small stores is applied both to gun-carriage and wagon with their limbers; and, indeed, up to the present time a full complement of tents for the accommodation of each gun detachment has been carried on the wagons—an admirable arrangement, and one highly conducive to the comfort and health of the soldier.

BUILDING CONSTRUCTION.—XVIII.

ROOFS—ARCHED RIBS.

In fixing the ribs of the dome of the Catholic church at Darmstadt (see page 138) in their places, the plates were, in the first place, merely nailed together; they were afterwards permanently connected, and prevented from altering their shape by bands of timber (*b b*, Fig. 173) running all round at regular heights; and these are bolted together as shown at *e e* (Figs. 174 and 175), the plates being further prevented separating laterally by the cross-pieces, *d d* (Fig. 174); the ribs are further stayed by additional bands running all round through the middle of their width. The openings for these timbers are shown in Fig. 173, and all the parts will be seen in their proper places in Fig. 176, which is a view of a portion of a dome, showing the lower ends of the main ribs, A A, and of an intermediate rib, B. The external and internal bands, *b b*, will be seen notched on to the ribs and united by the bolts, *e e*, at the sides of which are also seen the wooden cross-pieces, *d d* (Fig. 174); *c c* is the intermediate band, with wedges, *d d*, the purpose of which is to cramp the plates together laterally. The proper mode of projecting such views of domes will be given in a subsequent figure, it being desirable, at this stage, to contrast the De Lorme system with that of Emy.

This system has already been described and illustrated in former lessons, and it will therefore be sufficient to show how it has been applied. The example (Fig. 177) chosen for this purpose is a portion of the roof-truss of the riding-school at Libourne, near Bordeaux. The roof is not of the dome kind, but covers a building of a rectangular form.

The arch-rib, built up of five plates placed horizontally on each other, and joined as already shown, abuts against perpendicular double-posts, A, resting on corbels, B, built into the wall, which is one-third wider below than it is above this point. At the top of this wall-post is a strong cross-piece, C, resting on the stone cornice, D, which covers the whole width of the top of the wall; and this in its turn is laid on the wall-plate, which is placed on the *outer* face of the wall, so that it will be seen that the entire weight of the roof presses *downward*, or in the direction of the wall, and that the tendency of the whole truss must be to tie the walls together, not to force them outward; and this, as has already been explained in a former lesson (page 37), is the leading point to be kept in view in designing a roof. The principals, E, abut upon the cross-pieces, C, and are tied to the perpendicular by the struts, F, and to each other at the top by the collar-beam, G. To the frame thus formed, braces, H, I, J, etc., are attached, *converging to the centre of the arch-truss* (these braces are double), and clasp the arch-truss, the principals, and the ties, F, between them—being themselves bound together by means of blocks and bolts, the ends of which are shown in the illustration. The arch-truss is confined at the foot of the wall-post by an iron band, tightened by a screw-bolt. This arrangement is shown in Figs. 178 (the section), 179 (the side elevation), and 180 (the front elevation).

PARTITIONS.

Partitions are the internal walls which divide the building into separate rooms, and may be formed of solid walling, of timber framing filled in with brickwork, or may be made wholly of timber and covered with boarding or laths and plaster. This latter kind will be here considered. Partitions must be constructed on proper principles of trussing, so as to guard against cross strain, especially when placed over a vacuity without any support but at the ends, or when having to bear the weight of a floor above it.

Partitions should form a portion of the main carcase of the building, and should not be dependent upon, but should rather support the flooring. An important form of partition is given in Fig. 181, which represents a 6-inch partition so trussed as to support a floor above. It will be seen that A B C D is a complete roof truss, with queen-posts E, principal rafters F, and straining-piece G. This truss rests on stone templates in the wall. The sill at the bottom of the partition rests on a brick corbel built out of the wall, and on this is placed a stone template and an iron clamp. This supports a wooden wall-plate, or template, to receive the end of the sill.

The middle part of the partition is further to receive folding doors. The upright posts for this opening are placed under the queen-posts, are kept apart by a straining-piece, and pressed together at the top by braces, I I, which, being mortised into the sill, act as principal rafters again, and thus a second truss is formed under the other; whilst the whole structure is firmly braced up by the iron tie-rods at K, K.

FIRE-PROOF CONSTRUCTION.

A *perfectly* fire-proof construction has yet to be discovered, and therefore the author, guided by the best authorities of the day, of which Mr. Hoskings must rank as one of the highest, quotes from him the following remarks on fire-proof structures:—

"It is seldom that houses take fire from common accidents, such as occur to the lighter movable furniture and to drapery, but for the most part from the exposure of timber in or about the structure to the continued action of fire, or of heat, capable, sooner or later, of inducing the combustion of timber; and as the source is most commonly in some stove, furnace, flue, pipe or tube for generating or conveying heat, or for removing the products of combustion, much of the real danger to buildings by fire would be prevented by avoiding that degree of proximity between timber and all such things as can lead to its combustion.

"With the view of rendering their stairs, partitions, and floors as nearly as possible fire-proof, the French frame and brace with timber quarterings, much in the manner practised in England, excepting that the timber used in Paris is generally oak, previously well seasoned. The frame structure being complete, strong oak batten laths, from two to three inches wide, are nailed up to the quarterings horizontally, at four, six, or even eight inches apart, according to the character of the work, throughout the whole height of the enclosure and partition; and the spaces between the quarterings and behind the laths are built up with rough stone rubble, which the laths prevent falling out until the next process has been effected. This is to apply a strong mortar, which in Paris is mainly composed of plaster of Paris, which is there of excellent quality, laid on from both sides at the same time, and pressed through the opposite sides, so that the mortar meets and incorporates, embedding the stone rubble by filling up the interstices, and with so much body on the surface as to cover up and embed also the timber and the laths; in such manner indeed as to render the concretion of stone and plaster, when thoroughly set, an independent body, and giving strength to, rather than receiving support from the timber. The ceilings are constructed on a somewhat similar system. According to their practice, the ceiling must be formed before the upper surface or floor is laid, being formed from *above* instead of from below. The carpenter's work being complete, strong batten laths are nailed up to the

under side of the joists, as laths are with us; but they are much thicker and wider than our laths, and are placed so far apart that not more than perhaps one-half of the space is occupied by the laths. The laths being affixed—and they must be soundly nailed, as they have a heavy load to bear—a platform of rough boards is strutted up from below parallel to the plane formed by the laths, and at about half an inch below them. Mortar is then laid in from above over the platform, and between and over the laths to a thickness of from two and a half to three inches, and is forced in under the laths and under the joists and girders. The mortar being gauged, as our plasterers call it, or rather, in great part composed of plaster of Paris, it soon sets sufficiently to allow the platform to be removed onwards to another compartment, until the whole ceiling is formed.

"The plaster ceiling thus produced is in fact a strong slab or table in the body of which the batten-laths which hold it up are incorporated, and in the back of which the joists from which the mass is suspended are embedded. The finishing coat of plaster is then laid on. Such a ceiling will resist any fire that can act upon it from below under ordinary circumstances, and it would be difficult for fire to take hold from above in such a manner as to destroy the joists to which a ceiling so composed is attached, the laths and the under side of the joists being alike out of its reach; and consequently such a ceiling alone would diminish the danger of fire, although the floor above the joists were laid with deal boards.

"But a boarded floor in Paris is a luxury not to be found in the dwellings of the labouring classes, nor indeed is it to be found in any dwelling-house but those of the most costly description. But whether the eventual surface is to be a boarded floor or not, the flooring-joists are covered by a table of plaster above, as completely as they are covered by a plaster-ceiling below. Rough battens, generally split, and in short lengths stout enough to bear the weight of a man without bending, are laid with ends abutting on every joist, and as close together as they will lie without having been shot or planed on their edges. Upon this rough loose floor mortar of nearly similar consistence to that used for ceilings is spread to a thickness of about three inches, and as it is made to fill in the voids at the ends and sides of the floor-laths upon the joists, the laths become bedded upon the joists, whilst they are to some extent also incorporated with the plaster. The result is a firm floor upon which in ordinary buildings paving-tiles are laid, bedded in tenacious cement.

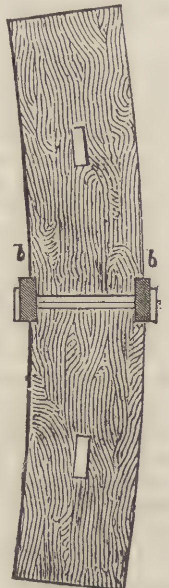


Fig. 173.

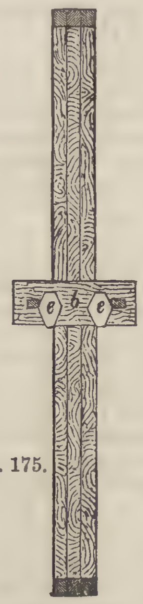
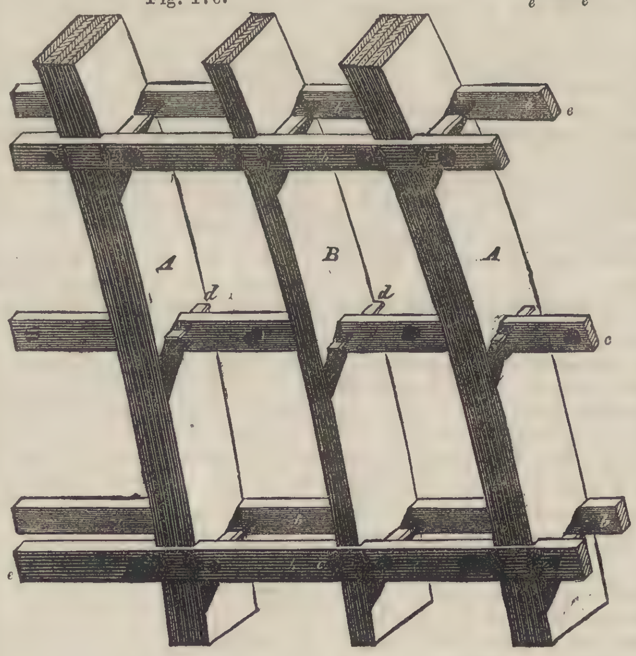


Fig. 175.

Fig. 174.

Fig. 176.



"It must be clear that the timbers of a floor so encased could hardly be made to burn, even if fire were let in between floor and ceiling. But it has been already stated that the practice of making these almost fire-proof floors is connected with the use of walls which have no timber laid in them bed-wise, and that the timber enclosures employed instead of walls and the internal partitions are rendered practically fire-proof, whilst the wooden staircases which economy dictates to the Parisian builders (the freestone which is used in building the walls being wholly unfit for the purpose) are also rendered unassailable by fire by being filled in with a solid mass of concreted rubble."

The author has thought it advisable to quote the above remarks of Mr. Hoskings on this subject, in the hope that, if it can be proved statistically that a smaller number of dwellings are accidentally destroyed by fire in Paris than in London, the system here described may be introduced into this country.

It must, however, be added that the subject of fire-proof construction has within recent years received much attention in England, and it is hoped the system may be generally adopted. One of the plans patented is based, firstly, on the use of wrought-iron girders combined with concrete, the patentees urging that for any part of a structure to be fire-proof all the materials employed should be absolutely indestructible, and hence no wood should be employed in the absolute construction; though when the fire-proof floor is completed fillets of wood may be bedded in the cement on the surface for the attachment of a carpet, or may even be continued across the room and boards nailed to them, as in the French system.

The iron girders, joists, and T-bars are fitted together before delivery, and after the main girders are fixed any boy or labourer can complete the work. The concrete should be mixed thick like the French *béton*, a flat board being held up underneath the T-bars whilst spreading it between the joists and girders. A concrete made of Portland cement or blue lias lime with gravel, ballast, or broken brick, in the proportion of one part of the former to eight of the latter, sets quickly and becomes as hard as stone.

The upper surface may be finished in fine cement, and the notched or slotted ends of the bars sustain the plaster under the flanges of the joists and girders, where there is a tendency to break away when any vibration takes place.

Independently of the fire-proof condition of floors constructed in the manner just described, there are other advantages to be derived from this mode of structure. In the first place, the access of rats and mice from one part of the house to another would be almost entirely if not wholly prevented, the spaces usually left between the flooring of the room above and the ceiling of the room below, the bad and hastily-mixed mortar commonly used in ordinary houses, the imperfect manner in which it is frequently laid between the bricks or stones of the structure, and the hollow, unplastered interval left between the skirting-board and the wall, affording ample opportunity for these vermin to make their way from cellar to attic at pleasure. Again, floors of concrete would prevent free passage of draughts and dust, which now make their way through shrunken boarded floors, and necessitate the placing of a layer of brown paper to save the carpet from injury by dust. On the other hand, concrete, finished with cement, being a better conductor of heat than wood, affords an argument in favour of covering flooring of this description with an exterior coating of planks, a carpet only between the concrete and the feet of the occupants of the room being barely sufficient to insure thorough protection from the chill that concrete would impart.

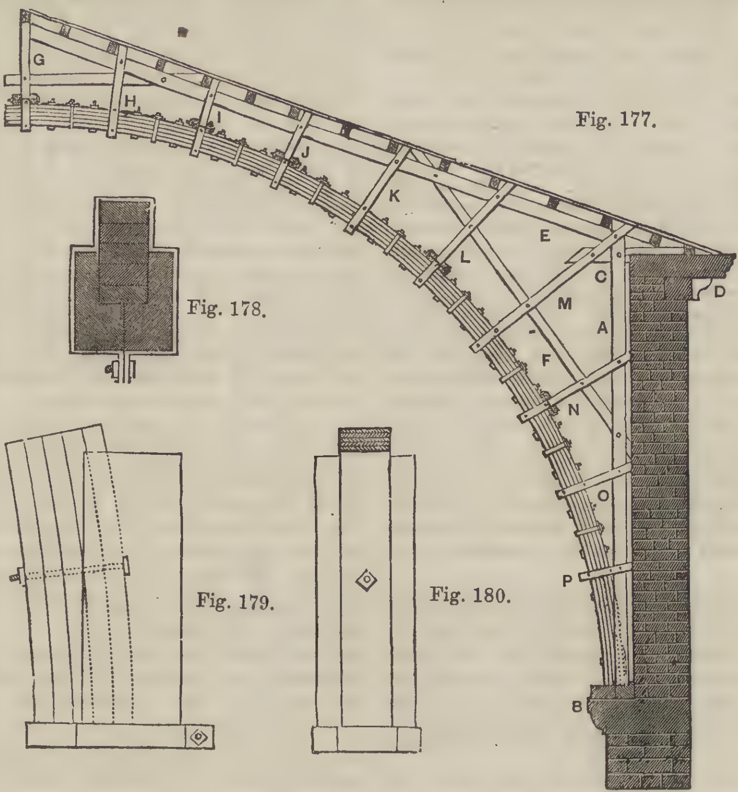


Fig. 177.

Fig. 178.

Fig. 179.

Fig. 180.

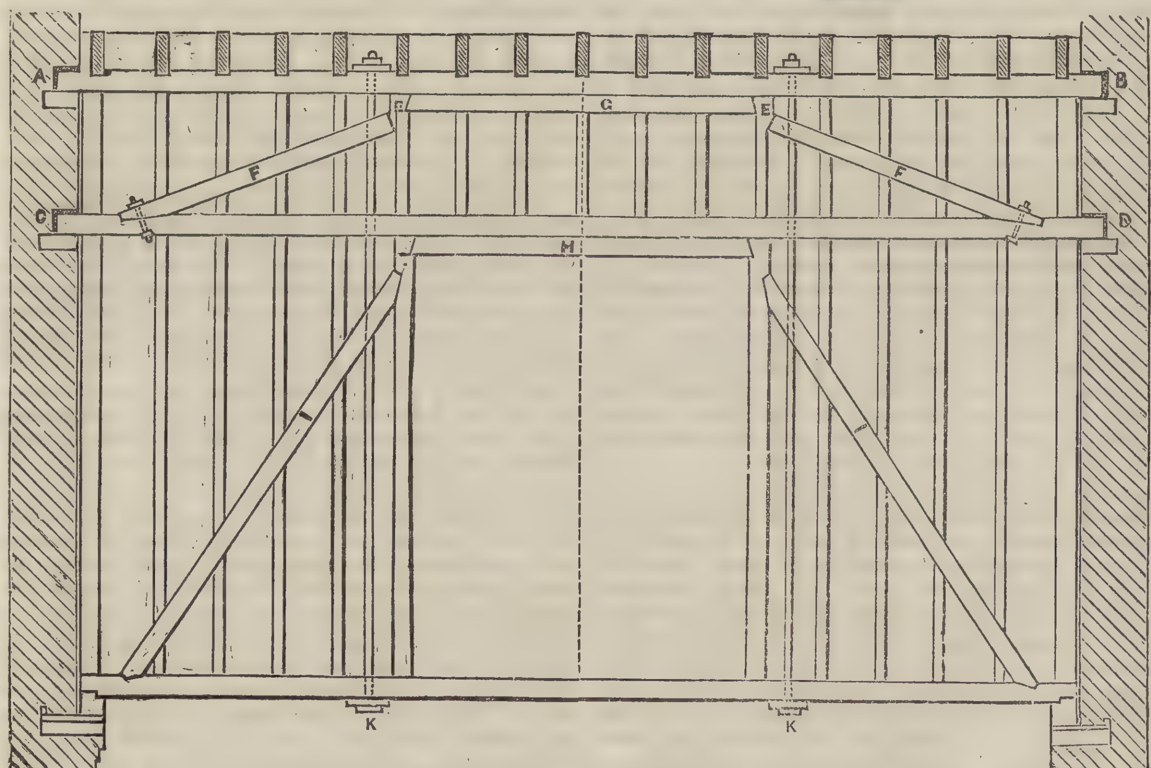


Fig. 181.—SIX-INCH TRUSSED PARTITION FOR SUPPORTING A FLOOR, WITH SPACE FOR FOLDING DOORS IN THE CENTRE.

FARMING AND FARMING ECONOMY.—II.

By Professor Wrightson, Royal Agricultural College, Cirencester.

PREPARATORY WORK IN SOILS—DRAINAGE—CLAY BURNING —LIMING—SUBSOIL AND TRENCH PLOUGHING, ETC.

Rural economy touches all the three kingdoms into which natural objects have been divided. Its foundation rests upon inorganic nature, whence, through the agency of incomprehensible laws, rises the vegetable world, and, lastly, by a further and more complex elaboration, animal life. As if to complete this cycle of change, the animal finally dies, and is restored to the inanimate domain, its component parts ministering anew to the development of future organisms. First, the soil, the air, and water afford scope for study; secondly, the cultivated crops form an interesting group; and, lastly, the live stock of the farm represent the animal kingdom. Every study, therefore, which bears upon these widely different subjects, becomes important to the student of agriculture; and hence we find chemistry, physics, and geology, physiology, botany, and zoology, all to some extent engaged in promoting agricultural advancement. In the following series it must be our object to restrict our attention to farming and farming economy, and to avoid the temptation of wandering into the domain of these and other sciences. In following our subject, we shall adopt the natural order already indicated, and consider (1) the soil, (2) crops, (3) stock, and, lastly, certain subjects connected with land management which do not strictly come under any of these heads.

Soil has been derived from previously existing rocks, which, during long ages, have been worn away and disintegrated by the continual action of natural forces. Hence the intimate connection of geology with agriculture; for, as rocks of various composition constitute large and distinct areas of country, so do we find the soil to vary. Chalk, green sand, oolitic limestones, Oxford and Kimmeridge clays, each furnish soils of definite character, varying in fertility, in tenacity, in altitude, and in other particulars.

All soils, wherever situated, are composed of clay, sand, lime, vegetable matter, and rocky fragments, and it is upon the proportions in which these familiar substances occur that fertility in a great measure depends. A fertile soil must be placed under favourable climatal conditions, both with reference to heat and moisture; it must possess an abundant store of available plant-food; and it must be in a proper mechanical condition. Heat and moisture are scarcely capable of control, while, on the other hand, the amount of plant-food and the physical or mechanical condition of the soil may be increased and improved. Hence we find two methods open to us in improving land—first, enriching the chemical resources of the soil, by adding to it substances valuable to plants as food; and, secondly, improving the mechanical condition of the soil. A soil may possess every necessary constituent for the growth of plants, but if these are unavailable we can hardly expect to see good crops upon it. If, for instance, the soil is wet or exceedingly tenacious, then, in spite of its good chemical composition, it will be more or less barren. Thus the improvement of the mechanical condition of the soil is fully as important as the addition of fertilising substances. Without further preface, therefore, we pass on to consider the methods ordinarily employed for improving the physical state of soils.

All soils do not require this preparatory work. Take, for instance, the case of light, dry land, in which the proper chemical substances occur in sufficient quantity. Such a soil will quickly repay the farmer for the expense of manuring; and this being the case, it is no matter of wonder that the lighter soils of this country have been long well farmed. The case of clay soils is somewhat different. They are richer than light soils in chemical constituents, but these riches are difficult to reach. More capital is therefore required to cultivate such land, and a longer time is necessary to bring it into a satisfactory condition. It is, therefore, in the management of clay lands that the preparatory work of mechanical improvement is most needed, and even after it is accomplished continual care is requisite so that every tillage operation may tend to induce a state of perfect tilth.

The means for the amelioration of soils are as follow:—(1) Drainage; (2) clay-burning; (3) claying, marling, and mixing; (4) liming; (5) warping; (6) subsoil and trench ploughing; (7) good cultivation.

Drainage is of all these the most important, and should precede every other operation. If land is wet, capital is uselessly expended upon it; but when rendered dry, every other improvement is likely to be followed with success. The subject of land drainage has been so recently placed before the readers of The Technical Educator, that it appears hardly necessary to revert to it at length. It may, however, be well to remind our readers that an efficient system of drainage is followed by a distinct rise in the temperature of the soil, by the introduction of air into interstices previously occupied by stagnant, and therefore unwholesome, water; by an evident improvement in the texture of the soil, and by the rainfall being rendered effective in assisting in the growth of plants, instead of absolutely checking vegetation, as must be the case in waterlogged soils. These good effects are followed by earlier and more abundant harvests, capability to grow a larger variety of crops, improved health on the part of both crops and live stock, and greater ease in the performance of all tillage operations. The soil is also in a better state for benefiting both from the use of manure and other improvements.

Clay-burning is a valuable means of rendering stiff land productive. It consists either in burning large masses of clay, or smaller heaps of about one cart-load each, and afterwards spreading the "ashes" upon the surface. Mr. Mechi uses a strong Ransome's plough, drawn by three horses abreast. "The earth being ploughed up, the fires are formed on the spot, the workmen placing a certain quantity of dried stumps, or wood of sufficient solidity, to maintain a body of heat, and enclosing the mass with large clods. These are carried by hand. Subsequently, as they get more distant from the fire, a barrow is used, and beyond that, a one-horse cart." Heaps of 200 cubic yards each are thus burnt. Mr. Pym, in a communication to the late Mr. P. Pusey, says, "The work begins in May, and is continued throughout the summer." He employs "roots and brush-fagots," and the cost of the wood is about 10s. for every 100 yards of clay burnt. Mr. Randell, of Chadbury, is a strong advocate for this means of improving land, and advises every tenant of stiff soil to adopt it. He considers fagots to be preferable to coal as a means of burning clay, because the soil is not burned so hard as is frequently the case where coal is used. One ton of coal will, with care, suffice for fifty cubic yards of clay. In clay-burning it is essential that the heat should be moderate, and that the work should not be hurried. The fire is kindled as above described, and as the heat spreads through the mass more clay is added, especially to those parts where the fire shows a tendency to break through the walls of the clamp.

"In clay-burning," writes a correspondent to the late Philip Pusey, "great skill, and judgment, and management are necessary. Indeed, I know of no part of husbandry that requires so much good sense, joined with experience." Mr. Randell also states that clay-burning requires great experience, and that without experience descriptions of the process are but of small utility. All writers are agreed as to the advantage of large heaps or clamps, of slow burning, and of encouraging a comparatively low rather than a high degree of heat.

Should the wind rise, thatched hurdles are used to prevent the fire from being unduly fanned; and if the flame should appear at the surface, fresh soil is added to smother it. Mr. Randell guards us against the use of large lumps, which will harden into intractable masses, but other writers do not agree with him in this last point, and speak of the lumps as readily falling under the influence of rain and changes of temperature. The cost is very uniformly calculated at about 7d. per cubic yard in the heap, but must vary with the price of coal or the value of wood used in burning. The effects are a larger yield of produce, the land more easily worked, and in many cases a considerable extension of root-cultivation and of sheep-farming. Dr. Voelcker experimented upon the changes effected in clay by burning, and showed that, when exposed to a low red heat, the amount of matter soluble in water was considerably increased. When the heat was increased to bright redness, the soluble matter diminished to even a less quantity than in the unburnt clay. Judicious burning, therefore, acts both in improving the texture by rendering the clay less tenacious, and also by improving its chemical condition.

Claying, *marling*, *chalking*, and in general *mixing*, soils may all be used with great advantage where the requisite conditions

occur. It is not uncommon to find such a combination of soil and subsoil that the latter may with advantage be raised and spread upon the surface.

Thus, in Norfolk, marling the sandy surface-soil is attended with great advantage. In Lincolnshire, where fen lands of peaty character occur, the nature of the soil has been greatly modified, and rendered suitable for the growth of cereals, by bringing up the underlying clay. Again, the upper chalk soils may be greatly improved by a dressing of the richer and more tenacious lower chalk; and, lastly, clay soils may be benefited, although in a less degree, by a liberal application of sand, as has been shown by Mr. Hope's treatment of his Dirlton Farm, in East Lothian. The marl, chalk, or clay being at a convenient distance, it is quarried, and carted to the field. In some cases pits and trenches are opened, and the material is brought up and spread on the surface.

Mr. Cambridge, of South Runcton, Norfolk, effected quite a revolution in the character of a light sandy farm by applying 54,055 loads of clay to 286 acres 2 roods 25 poles of land, or 188 loads per acre. In other cases 50 and 80 loads per acre have been employed with good effect. The result of claying and marling is an increase in the fertility of the soil, greater strength in the straw of cereals, more certainty in the cultivation of clovers and root-crops, and a greater power on the part of the soil to resist drought.

Liming is a valuable means of both enriching and improving the texture of soils. It exerts a threefold influence, first as a plant-food, second as an ameliorator of the texture, and thirdly as a neutraliser of acids in the soil. It is, perhaps, most beneficial in the case of newly "broken up" land, especially of a peaty or vegetable character. Lime is also a valuable application for clay soils in general, and where soils are naturally deficient in lime it may be applied at intervals of twelve years with excellent results.

Lime is obtained by heating the carbonate to full redness for an hour or two. For agricultural purposes, the impure (native) carbonate is burned in a kiln, the cavity of which is usually either egg-shaped or in the form of a truncated inverted cone; it is charged with alternate layers of coal and limestone, and the fire is kindled. The lime as it is burned gradually sinks down, and is removed by openings at the base of the furnace, and a fresh supply of coal and limestone is supplied at the top of the kiln. (Miller.)

The following are usual dimensions for lime-kilns:—Height inside of kiln, 21 feet; diameter at top, 7 feet; diameter at middle, 8½ feet; diameter at bottom, 3 feet. The kiln ought to increase in width from the bottom upwards, till the greatest diameter is reached at the height of 11 feet; the walls are then carried up perpendicularly for four feet, after which the space is narrowed towards the top. The building material should be good stone, well built, and the walls should not be less than three feet thick at any part. The inside should be cased with fire-brick, and round the top there should be some large fire-burrs made to pattern, the whole to be well cemented with fire-clay. At the bottom there must be a space two feet square for drawing out the lime, and from the top of this to the outside there must be an archway for facilitating the same. Such a kiln will hold 700 to 800 bushels of lime, and will burn at the rate of 250 bushels a day. To furnish 100 bushels of lime, about 6 tons of mountain limestone and from 25 to 40 cwt. of coal will be required. This will make the cost about as follows (see "Cyclopædia of Agriculture"):—

	£	s.	d.
6 tons of stone, worth 10d. per ton ...	0	5	0
Say 1 ton 15 cwt. of coal, at 4s. 6d. per ton	0	7	10½
Lime-burner, about 2s. per 100 bushels ...	0	2	0
Kiln tools, interest on capital, etc., say ...	0	1	0
Or, per 100 bushels	0	15	10½

The weight of a bushel of lime varies with the quality of the stone whence it is derived, and is variously estimated at 77 lb., 93 lb., and 80 to 100 lb.

Lime is applied at the rate of from 3 to 9 tons, or from 100 to 300 bushels. It is carted either into large heaps on the headland, where it remains until it is slaked; or it is deposited in small heaps (about ten to the cart-load), covered with a little earth, and then left to slake. In both cases the subsequent work consists in spreading it over the surface, after which it is lightly ploughed or cultivated in.

Warping gives an entirely new surface to soil. It may be best explained as a process by which the suspended mud which occurs in certain rivers is allowed to deposit itself upon a prescribed area of land. The chief district where this improvement can be effected is in North Lincolnshire and South-east Yorkshire, on either side of the Humber and its tributaries. These rivers carry an immense quantity of mud to the ocean, and naturally deposit it at the mouth of the Humber. By a system of sluices, open ditches, and embanked enclosures, the muddy water is diverted during spring-tides, and made to flow where it is required. As the water expands over the "compartment" it deposits its mud; and, by regulating the flow by means of "call-banks" and "inlets," an even coating of from one to three feet is at length obtained. Warping is a costly operation, incurring an expense of from £12 to £20 per acre. It may, however, be regarded as securing permanently good land upon an area which previously may have been almost worthless.

Subsoil and *Trench Ploughing* have been advocated by many agriculturists. Both may be spoken of as valuable means for deepening the available feeding-ground of plants, and both are useful when used judiciously. Indiscriminate deep culture is not, however, to be recommended, as in some cases it might be hurtful, while in others no appreciable benefit follows its adoption. Subsoil ploughing may be defined as a method of disturbing or pulverising the subsoil; while trench ploughing consists in bringing up the subsoil, and mixing it with the surface-soil. Subsoil ploughing is seldom injurious, but the rash commingling of subsoil and soil may be attended with either good or bad effects. A considerable mass of evidence collected by the late Mr. P. Pusey upon subsoil ploughing tended to show that stiff clay soils are not permanently benefited by it, and that the greatest good was effected in the case of lighter soils, where at a few inches beneath the surface some sort of "pan" or indurated condition of soil occurred. This pan may either be the consequence of the long-continued passage of implements and horses over the land during years of shallow cultivation; or it may consist of calcareous and gravelly matter, compacted together so as to prevent the passage of either water or plant-roots; or it may be what is well known as "moor-band-pan," an ochreous or ferruginous deposit, which binds the earthy materials, such as gravel and sand, into a compact concretion. Where land is thus affected the drainage is defective, the soil is alternately "ankle deep" and sun-scorched; and the crops, although promising in their early stages, fail as they approach maturity.

In such cases a strong subsoiler, drawn by four horses, is a most valuable means of improvement. Clay soils, on the other hand, although temporarily improved by the passage of the subsoiler through them, very shortly relapse into their former condition, and all traces of the work disappear. The Marquis of Tweeddale has improved an extensive tract of poor, high-lying soil in Haddington, known as the Yester Estate, by thorough drainage, followed by the use of what he has named the "subsoil-trench plough." This implement consists in the first place of a subsoiler or coulter of iron, which, as it passes through the subsoil, breaks and opens it. Immediately behind this coulter is an inclined plane or platform, which receives the subsoil, and, as it passes backwards, delivers it at a higher level among the surface-soil. The advantages claimed for these operations are an increased depth of soil, greater facility for the escape of water through drains, and greater ability to withstand severe droughts.

General Cultivation.—After land has been drained, and otherwise brought into a state in which it can be profitably farmed, it must be properly cultivated. The foregoing operations, when once well done, are to a great extent permanent. Cultivation, on the other hand, is a constantly recurring work. The object of all cultivation may be said to be twofold: first, to bring the land into a proper tilth for the contemplated crop; and secondly, as a means of destroying vegetable and animal pests. It is not our intention to enter into details respecting ploughing, harrowing, "cultivating," and rolling, but rather to lay down the principles which, if properly carried out, will lead to "clean" land and a good state of tilth. First, then, in dealing with land, we must endeavour to act in concert with Nature, rather than in opposition to her. Atmospheric influences are of an importance which cannot well be overrated, and hence

the need of autumn cultivation, by which land is exposed to the greatest changes in temperature. The most thorough cultivation is required during the period of "fallowing." This occurs at intervals of from three to seven years, according to the character of the soil, and it is then that the land is thoroughly cleansed from weeds, and brought to the finest possible tilth. The precise conditions which the farmer wishes to induce will depend upon the kind of fallow it is proposed to make. Where a "bare fallow" is necessary, a rough condition of soil throughout the summer is desirable, that weeds may be destroyed by the scorching sun of June and July. This condition of land is best obtained by spring ploughing. Where a root-crop is desired, the object is to obtain a fine tilth, to render the land clean, and at the same time to retain the moisture in the soil for the use of the root-crop. In this case, spring ploughing and spring working are scarcely desirable. By autumn cultivation is meant, first shallow ploughing (or paring of the stubbles immediately after harvest, so as to detach the weeds from the deeper layers of soil), harrowing and rolling, and afterwards collecting and burning the weeds in heaps over the field. The ashes are then spread, manure is carted on to and spread over the land, and the field is then ploughed deeply and left until spring, when it will be found in a finely-pulverised condition, owing to exposure throughout the winter. Ploughing such land again in the spring should be avoided if possible, and the less cultivation used at that time the better will be the prospect of a root-crop. By this means a fine surface and a moist condition of soil are both secured. Exceptional treatment is, however, so often necessary that we must be on our guard in accepting any prescribed course of cultivation, and remember that where every field has its own peculiar soil, and every season its own eccentricities, it is impossible to frame rules for action. Autumn cultivation is, however, always safe, and should be followed out as extensively as possible. Its advantages may be summed up as follows :—It ensures the beneficial action of the frost upon the land; it destroys the larvæ and eggs of insects and seeds of weeds; it conserves moisture in the soil. Where steam cultivation has been introduced, all these advantages are most perfectly realised. Clay lands are ever the most difficult to deal with, and up to this time the expense attending their cultivation, together with their want of adaptability for growing root-crops, has caused them to be less sought after than light lands. Steam cultivation is, however, destined to develop the resources of these soils in a remarkable degree. Clay lands require to be worked with much judgment. They should be worked dry; their tenacious character must be modified by applications of lime, by burning, by good dressings of farm-yard manure, and by avoiding meddling at improper seasons. They must also be cropped with wheat, beans, and clover; and the fallow portion must frequently be worked without a crop. When fallow crops are grown, they must be removed from the land before wet weather sets in during autumn. The cultivation of light land is easier than that of clays. These soils require compression rather than lightening up. Thus we find sheep are fed upon root-crops in the winter, for the purpose of consolidating the soil. The light-land farmer is always insisting upon the importance of having his land "firm," while the clay-land farmer endeavours to counteract the heaviness and retentiveness of his land. Such is a brief statement of the means at our disposal for improving the texture of clay soils; it yet remains for us to consider how they may be enriched by the addition of fertilising materials. Further information upon the points touched upon in this chapter will be found in "Morton's Cyclopædia of Agriculture" (Blackie and Son), and the "Journals of the Royal Agricultural Society" (John Murray).

THE STEAM-ENGINE.—X.

By J. M. Wigner, B.A.

VERTICAL ENGINES—COUNTER—MARINE ENGINES—PADDLES—SCREW—GOVERNORS—DIRECT-ACTING, TRUNK, AND SIDE-LEVER ENGINES—HYDRAULIC PROPELLER.

Horizontal engines can be fitted with a condenser as easily as those which have a beam; but this is not very frequently done: as a general rule, they are of the non-condensing class. There is an almost endless variety in the form given to these engines, but the action of all is very similar to that of the one we have already described.

There is, however, one modification which we must just notice in passing, and which is known as the "oscillating engine." In this form the cylinder is mounted so as to vibrate on an axis situated at its lower end, or else at the centre as in the figure. The guides which control the piston-rod and the connecting-rod are here entirely dispensed with, and the piston-rod is connected directly to the crank, so that as it moves up and down the whole cylinder vibrates from side to side, and thus all strain on the rod is avoided. Fig. 38 will render this quite clear.

The steam-pipe is so arranged that it enters at the axis, and the valves are moved in the usual way by an eccentric. In an engine of this kind the greatest simplicity is attained, and the number of working parts is reduced to a minimum, but it has never been very generally used as a land engine. In steam-vessels, however, the principle has been carried out very successfully, as will be shortly explained.

There is one other useful appendage to an engine which we must just describe here. This is known as the "counter," or engine clock. Very frequently it is important to know the rate at which an engine is working—that is, the number of strokes per minute it is making. The "counter" accomplishes this. It consists of a dial with suitable attachments, and is so made that it registers the number of strokes or revolutions made since it was set, and thus we can at once tell the number it is making per minute or per hour.

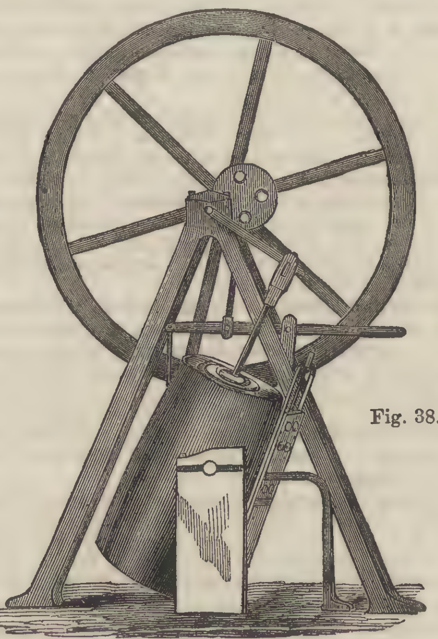


Fig. 38.

Soon after the steam-engine had begun to be at all generally adopted, attention was directed to the discovery of the best manner of rendering it available for purposes of navigation. Great practical inconvenience had long been caused by the dependence of vessels on the influences of wind and tide, and, even before steam was suggested, various mechanical contrivances, set in motion by the power of man or of horses, had been devised for the purpose of propelling vessels.

The most plausible of these consisted of a wheel carrying a number of floats round its circumference, after the plan of our paddle-wheels. About the year 1788, a Mr. Miller appears to have constructed a small vessel of this class, and to have driven the paddles by means of a steam-engine. It was only a small vessel, and was used for experimental purposes on a lake in his grounds; but the attempt was so far successful, that various modifications and improvements were soon made by other inventors, among whom the most prominent were Taylor, Symington, Fulton, and Bell.

We must not, however, pursue the history of the marine

engine, interesting though it be to trace its gradual development; nor can we, in a brief series of papers like the present, inquire fully into all the details of the construction of marine engines generally, more especially as we should find that almost every maker has some special form or peculiar construction which he considers the best. All that we can do is as briefly as possible to refer to the principal points in which they differ from other engines. It is clear, in the first place, that since the engine has to be carried on board a vessel, in which as much room as possible is required for the accommodation of passengers and cargo, it must itself occupy as little space as possible, and also must be as light in its construction as it can be, consistently with having sufficient strength. For the same reason, too, the whole must be so arranged as to consume as little coal as possible. As a general rule, the vessel on starting must carry the greater part, or the whole, of the coal she will require during her voyage, since there are not many foreign stations where it can easily be procured, and even at these a greatly enhanced price has to be paid for it, usually three or four times the price that would have to be paid in this country. When we remember that in many large vessels the consumption may amount to thirty or forty tons a day, and that often they have to run very considerable distances without stopping, or without any opportunity of coaling, it will easily be seen how important it is that the amount consumed, as compared with the work performed, should be reduced to a minimum. The actual amount consumed increases greatly with the speed, and hence in the navy, on occasions where there is little need of dispatch, a great saving may be effected; in the merchant service speed is generally required, as more voyages may be thus accomplished in the same time.

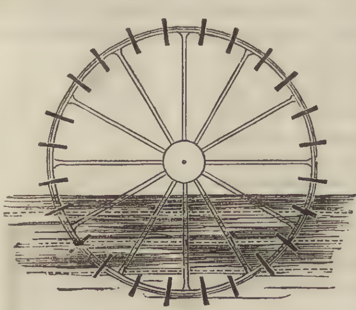


Fig. 39.

From their greater economy in fuel and other causes, low-pressure or condensing engines are almost exclusively employed in this country. Several boiler explosions, too, have occurred with high-pressure engines, and this has tended to strengthen the feeling against them.

There are two modes by which the power of the steam-engine is usually made to impart motion to the vessel. These are by means of paddle-wheels or by a screw-propeller. The former plan was first introduced, and was for a long time exclusively employed, but it is now rapidly giving way to the screw. In it a large and strong shaft passes from side to side of the vessel near the centre, and on each end of this a paddle-wheel is firmly secured. This consists usually of two or three metal rings, with paddle-boards or floats fixed to them. As the wheel rotates, these act on the water like oars, and thus propel the vessel. In Fig. 39 such a wheel is represented in section, and several dotted lines are drawn across it to represent different depths to which it may be immersed in the water; by observing the different angles at which the floats strike these, we shall easily see what an important thing it is to allow them to dip the right distance below the water. If the wheel be too deep, as it is in the figure, much power is consumed in moving the floats through the water, and, as will be seen, they oppose one another to a certain extent; if it be too high, they get but little hold.

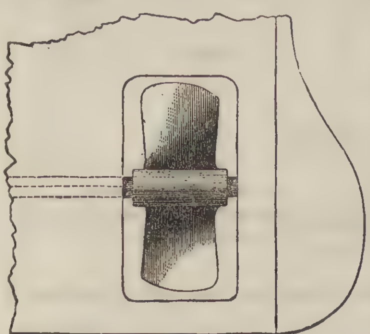


Fig. 40.

Now when a vessel leaves the docks to start on her voyage, she is usually somewhat deeply immersed, and hence the paddles do not act as well as they might. As the voyage progresses, some of the coal is consumed, and thus the vessel rises higher and higher out of the water. In some cases there will be a difference of three feet, from this cause, between the draught of water on leaving the port and on arriving out. It is clear, therefore, that the paddles must be adjusted for the medium displacement; but still there is a loss of power, and this is a considerable drawback to the employment of this mode of propulsion.

To obviate this in a measure, "feathering paddles" have been introduced. In these, each float, instead of being fixed to the wheel, is mounted so as to turn on a pivot. An eccentric is then fixed to the end of the shaft, and from this rods lead to the floats, and thus cause them to enter the water almost vertical, and to remain so as they pass through it. A considerable saving of power is thus effected, but the wheels are much more liable to get out of repair, besides being very greatly increased in weight and in cost, and hence they are not generally adopted.

In screw steamers the shaft runs lengthwise along the vessel, and the screw is placed at the stern, in an opening between it and the rudder-post. Much of the efficiency of the screw as a propeller depends upon the lines of the vessel. In several of the early experiments, the stern of the vessel was not suitably moulded, and, as a result, the performance of the screw was greatly inferior to the anticipations which had been formed. An idea of the construction of a screw may easily be formed by imagining a thin plate of metal on its edge, wound round a small spindle, or by supposing the thread of an ordinary screw extended outwards from the centre. By the pitch of the screw is meant the length of spindle in which the thread completes one revolution. In many screws the pitch is great, and then two or three threads, parallel to one another, are used.

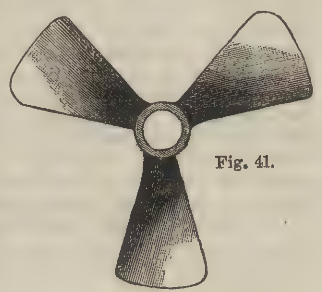


Fig. 41.

If we have such a screw with three threads, and cut off it a slice so thick as to contain about one-sixth part of a full turn, the piece cut off will clearly have three blades or arms projecting from it, each of which will be twisted partly round, as shown in Fig. 41. Each of these cuts the water as it revolves, and thus pushes forward the vessel just as a screw would if its nut were fixed while it revolved. At first a much longer screw was used, but it is now found that a short portion will answer as effectually. The usual plan is to make the pitch of the screw about eight or ten feet; sometimes, however, it is considerably greater than this. There exists, however, an immense diversity in the forms given to the screw, and in the number of blades; the general number is either two or three, but sometimes there are four, and in Captain Ericsson's propeller there are six, but these are fixed on a short cylinder connected with the shaft by three or more arms. Many vessels are now fitted with twin screws, one being placed on each side of the rudder.

Whether, then, the vessel is propelled by a screw or by paddles, we have in either case a horizontal shaft which has to be driven by the engine, and the engine must be so arranged as to impart a regular movement to this. One difficulty, especially in the case of a screw steamer, is caused by the necessity for the shaft to be low down in the vessel, since the screw should be completely submerged even when the vessel is light.

Then, too, a fly-wheel is inadmissible both on account of the space it occupies, and of the irregular motion of the vessel. This difficulty is usually met by employing two or three engines, so arranged that when one is at its "dead point" the others shall be working fully, and thus a nearly uniform motion is secured.

In a rough sea, however, there are very great fluctuations in the strain on the engine; at one moment the propeller is deeply immersed, and then again it is lifted quite out of the water. This causes the engine to "race" considerably, and a

man is sometimes stationed by the throttle-valve to move it by hand, and prevent this as far as possible. Various kinds of governors have been tried with the same object, the ordinary balls being clearly unsuited, as the motion of the vessel would interfere with their action.

"Silver's momentum governor" is that most generally employed, and it is found to answer well. It consists of a small but heavy fly-wheel set in motion by the engine, the driving power being transmitted to it by means of a spring. The wheel moves at a considerable speed, so that its rate of movement is not easily altered, much power being stored up in it. Now if the rate of the engine be suddenly increased, the governor tries to maintain its own speed, and in so doing acts by means of the spring on the throttle-valve, and partially closes it. In a similar way a decrease in speed opens the valve, and thus a nearly uniform rate is maintained.

The shafts which move the screw or paddles have a very great strain on them, and must therefore be carefully made and tested; even then, however, they often crack after a few years' use. The iron appears to undergo a change by the continued jar, and to become brittle. Steel shafts have been tried, but have not been generally approved of, as they often break without giving any signs of warning, while in the case of wrought-iron shafts a small flaw usually appears first, and thus allows a sufficient space of time to prepare a new shaft, or to change the old one.

In a screw vessel the propelling power is at the stern, and thus the vessel is moved onwards entirely by the thrust of the shaft, and suitable arrangements have to be made to withstand this. Sometimes a thrust-block of steel, securely fixed to the engine, is placed at the fore-end of the shaft; but the more common plan is to employ a "collared bearing." In this the axle at one of the bearings, instead of being plain, is cut into six or eight deep square grooves, and corresponding grooves are cut in the block, which thus takes the strain. The friction in this case is of course very great, and much care is required to prevent the bearing becoming unduly heated.

The bearing where the shaft passes out of the vessel, at the stern, is usually lined with pieces of lignum vitæ or some other hard wood, and the little water which leaks through lubricates it and keeps all cool.

There are great varieties in marine engines, but most may be arranged in two or three classes. The first of these are known as "direct-acting" engines; in these the piston-rod is joined to the connecting-rod, and thus acts directly on the crank without the intervention of any side levers or other similar contrivances. In this way a considerable saving of room is effected, and the machinery is rendered less cumbrous and complicated; but there is the disadvantage that the stroke must of necessity be somewhat short, and the connecting-rod likewise is short, so that there is much additional wear and strain. Some plan, too, has to be devised for making the piston-rod move in a straight line, as the strain on it from the short connecting-rod is very great. This is sometimes effected by means of a series of jointed rods which form a "parallel motion;" in other cases a cross-head is attached to the piston-rod, and is made to slide between fixed guides which keep it in its place; while in other engines, again, the cylinder itself is made to oscillate on trunnions fixed near its centre, the steam being allowed to enter through these. The piston-rod is then connected direct to the crank.

It is by no means uncommon for two of these plans to be combined, and thus we sometimes see steamers in which there are three cylinders, the outer ones being fixed, while the centre one is made to oscillate; nor is it unusual for the fixed cylinder to be inclined or inverted so as to act more readily on the shaft. The variety is in fact so great, that scarcely any two engines are built on the same model.

There was at first some difficulty in imparting a sufficiently rapid rotation to the screw-shaft, and the plan was introduced of multiplying the speed by means of toothed gearing. In this form a large wheel is put in motion by the engines, and the teeth of this work in those of a smaller one on the crank-shaft, and thus the speed is largely increased. This plan answers much better than might be expected, and when the teeth are made of hard wood and well-shaped, there is little wear, and they work very steadily. It was, however, soon found that the speed of the piston might be safely and easily increased, and at the same time the stroke might be shortened; and hence "geared" engines are going out of use, and in nearly all cases the motion is now imparted direct to the shaft.

Another kind of engine, frequently employed, is known as the "trunk engine," and this is one of the most compact forms made, since in it the piston-rod and parallel motion are rendered unnecessary. A hollow trunk or cylinder is fixed to the upper face of the piston, and is made to work steam-tight through a stuffing-box in the cylinder cover. Sometimes, to impart additional strength and to equalise the strain, this trunk is continued below the piston, and made to pass through another stuffing-box in the lower end of the cylinder. The connecting-rod is then fixed to the top of the piston inside this tube, which is of sufficient dimensions to allow room enough for the rod to oscillate in it from side to side as the crank revolves. The annexed sketch (Fig. 42) will render this clear.

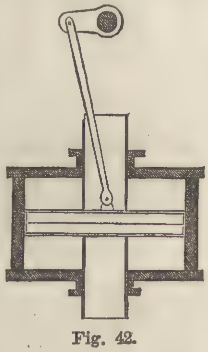


Fig. 42.

It will at once be seen that in an engine of this description the effective area of the piston is diminished by the space occupied by the trunk, but this loss may easily be compensated for by slightly enlarging the cylinders. When these are placed horizontally, as is often the case, all the machinery can be placed well below the water-line, and this, especially in the case of vessels of war, is a very important thing, since a shot will seldom penetrate a vessel far below this level.

The engines originally adopted for use on ships were a modification of the beam engine, already described, and are known as side levers. In these, instead of an overhead beam, one was placed at each side of the cylinder. These were connected at one end to a cross-head fixed to the piston-rod, and kept vertical by guide-rods or a parallel motion; and at the other end, to the connecting-rod which imparted the motion to the crank-shaft, as Fig. 43 will show. The benefits of this plan were that a much longer connecting-rod could be employed, and thus the movement was transmitted more evenly, and also that the parts were well balanced; but direct-acting engines save so much in space and in weight, that they are fast superseding these.

There are a few special features common to nearly all marine engines, to which we must now refer. On board ship the utmost care has to be taken to guard against fire, and hence in the boilers the furnaces and flues are always entirely internal, being surrounded in every direction by a layer of water. They are usually made sufficiently large to allow a boy to enter and clear out any deposit, as this would injure the plates if allowed to accumulate against them. The flues should also be so arranged that the steam, when generated, can easily rise. If it remains long in contact with the plates, it keeps the water from them, and thus allows them to become unduly heated.

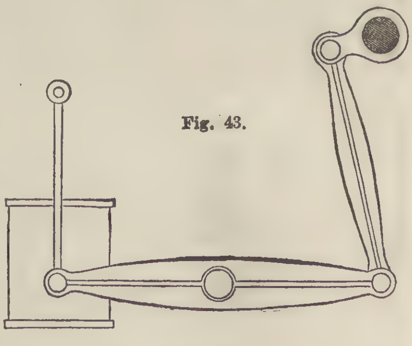


Fig. 43.

The utmost care is, of course, required in feeding the boiler so as to maintain the water at a uniform level, and here there is an important point of difference from land boilers—the feed-water is salt. Now only pure water passes over in the form of steam, and hence the water remaining behind in the boiler rapidly becomes charged with the various salts which enter into the composition of sea-water. The result of this is to cause a thick deposit of scale on the boiler, and at the same time to corrode the plates. This difficulty is usually overcome by blowing off into the sea a certain portion of the contents of the boiler, and thus getting rid of the excess of salt, and maintain-

ing the water at a proper density. The engineer in charge must frequently test the water in the boiler, to make sure that this is properly done. As a general rule, from a quarter to a half of the amount of water supplied to the boiler has to be "blown off" in this way, and the best plan is to have a special cock provided for the purpose, and capable of exact adjustment. This should be kept continually open to such an extent as to allow a constant stream to escape, sufficient in quantity to keep the water at a suitable degree of saturation.

It is best to take the blow-off water from the surface, as various particles of "scale" and other impurities are carried there by the ebullition. A large shallow pan is therefore placed a few inches below the surface of the water, and the blow-off leads from the centre of this.

There is manifestly a very considerable loss of heat by this plan, and to obviate this to a certain extent surface condensers are now generally adopted. In these the condensing water is not allowed to mingle with the steam, but is made to pass through a series of pipes on the surface of which the steam is condensed. In this way the condensed water is perfectly fresh, and the boiler is fed with this, so that the same water is used over and over again. This plan alone will not answer, however, as a portion of the steam escapes and is lost, and besides this, the water soon becomes so foul from the grease used, and the particles worn off the bearings and other parts, that it corrodes the plates to a great extent, and causes the engine to "prime" very much.

The best plan appears to be to work the boiler at first with salt water till a thin scale has formed, which serves to protect the plates. The boiler is then fed more from the condenser, and less from the sea; but a certain portion of sea-water is always used so as to keep the water clean, and to maintain the density in the boiler about equal to that of the sea. The less oil or tallow is used, the better. In this way there is a much less amount of "blowing-off" requisite, and the boilers are kept in good condition.

Whichever form of condenser is adopted, it is very desirable to make arrangements by which it can, if necessary, be fed from the bilge of the vessel instead of from the sea. In this way a leak in a vessel may often be kept under, and large ships have sometimes been thus saved.

In engines used in river steamers the mud with which the water of the stream is frequently impregnated is sometimes a source of difficulty and disaster. Thus in the large and powerful steamboats which run on the Mississippi the quantity of mud held in suspension in the water of this river below the mouth of the Missouri frequently causes an explosion in the boilers by accumulating in a thick stratum at the bottom, as the salt accumulates in a marine boiler. The only remedy is to blow the water out of the boiler from time to time. This, however, is frequently neglected, and has caused many of the terrible steamboat accidents that have occurred on the American rivers.

Before passing from the subject of marine engines, we must just refer to an entirely novel kind of propeller recently introduced, and tried in H.M.S. *Waterwitch*, which was launched in 1866. In this there are neither screws nor paddles, the propelling force being entirely derived from the reaction produced by two large jets of water, thrown from nozzles placed at her sides a little below the water-line.

In the centre of the vessel is a large horizontal turbine fourteen feet in diameter, fitted with twelve blades. This draws the water from the sea, and forces it into a large chamber, whence it passes along rectangular pipes to the nozzles. Of these there are four, two pointing forwards and two aft, and the water may be made to issue from either pair at pleasure, and thus propel the vessel in either direction, a rudder being placed at each end. The vessel was tried and compared with the *Vixen* and the *Viper*, two vessels nearly similar in size and make, but fitted with screw-propellers, and the result was very satisfactory. The speed attained by the *Waterwitch* was about midway between that of the other two vessels, being about 9¼ knots.

In turning about, however, the other vessels, which were fitted with twin screws, had the advantage; but this could probably be easily remedied by altering the nozzles, so that they could eject the water at an angle instead of merely in the direction of the vessel's length. This plan has not, however, been adopted in many other vessels.

SANITARY ENGINEERING.—III.

PHOTOMETRY, OR THE MEASUREMENT OF GAS AND OTHER LIGHT.

In two previous papers we have dealt with the subjects of the "Manufacture of Gas by Public Companies," and "Gas-burners and the Economy of Gas Consumption:" we are now going a step further in the same direction, and shall endeavour to explain how gas-light is measured, how one burner can be compared with another, and also how the comparative lighting powers of different samples of gas can be ascertained and defined. This is done by means of an instrument called a photometer, or light-measurer, which consists of a long rod—five feet is not an uncommon length—carefully graduated from end to end, and fixed in a perfectly horizontal position; at either end of the rod, at adjusted foci, are the means of fixing either sperm candles (for a reason hereafter to be explained) or various descriptions of gas-burners—arrangements, of course, being made by means of flexible tubes or otherwise for the laying on of the gas—and the operation of the machine is as under. The experiments must be conducted in a dark room, from which every ray of natural or artificial light is carefully excluded, with the exception of the lights which are the subject of investigation—*i.e.*, which have to be measured. Backwards and forwards along the rod with its fixed light at either end a small metallic frame travels which carries a screen, a few inches square, of paper, one portion of which is saturated with oil so as to render it translucent, while the other portion remains in its natural state. When the screen is close to the light at the one end, the shadow thrown by the opaque portion of the paper is distinctly visible on the side opposite to the light; and when moved along the side to the other end, the converse result is obtained. At some given point between the two lights there is no shadow thrown either way, the power of the two lights balancing each other; the position of the screen on the graduated scale indicates the comparative power or measurement of the light.

Now as to the way in which this is practically applied. The *unit* of calculation adopted in practice is a sperm candle one-sixth of a pound in weight and burning 120 grains per hour; this is called a "standard candle," and the "standard burner" in use in London is Sugg's London argand, Number 1, which will indicate by the photometer a light varying with the quality of gas—of, say, from 13 to 17 candles. We mention these figures, not as the extreme which can be reached, for cannel gas of superior quality will give a much higher result, as we shall show by some figures in the sequel; but as pretty well including all the ordinary qualities of common coal gas likely to be supplied for household purposes, and showing the way in which legislation is brought to bear upon the subject, to protect the public and give some guarantee as to the quality of the gas supplied—a necessary precaution, gas being, more especially in county districts, almost a monopoly from the mere necessity of the case. We give an extract from one of the half-yearly "instructions" issued by the metropolitan gas referees to their examiners:—

"The burner to be used for testing the common gas of the Gas-light and Coke Company (which is required to have an illuminating power of 16 candles) shall be Sugg's London argand, Number 1, with a $6'' \times 2''$ chimney; and for the gas of the Imperial Gas Company and the South Metropolitan Gas Company (which is required to have an illuminating power of 14 candles) Sugg's London argand, Number 1, with a $6'' \times 1\frac{3}{4}''$ chimney. If at any time the gas flame tails over the top of the chimney, a $7'' \times 2''$ chimney shall be used for the 16-candle gas, and a $6'' \times 2''$ chimney for the 14-candle gas.'

It is evident that the power of comparison thus obtained by the photometer may be applied to the comparison of larger or smaller burners, either with the standard candle or with each other, and it will thus be evident that the figures we may quote will not be in any way hypothetical, but all founded upon the basis of actual experiment. The popular way of describing the quality of gas is also thus explained: 14 or 16-candle gas, as the case may be, indicating the amount of light given by the gas when burned from a standard burner and compared with standard candles.

A curious and handy little experiment may be tried with common fish-tail burners:—Let a small size Number 3 fish-tail be fixed to the photometer *in situ*, and when all is arranged let

the light be suddenly blown out; when the burner is sufficiently cool, place upon the top of it, where, as it is carefully turned, it will easily stand, another fish-tail burner of larger size, and then, turning on the gas, light the upper burner. Although the tube and pressure and every circumstance remain exactly the same, the photometer will indicate a most remarkable increase in the quantity of light—double in some cases or more according to the size of the upper burner.

Having described in general terms the working of the photometer, we may here note various points to be attended to in order to secure an accurate result.

The length of the chimney used with the burner is of great importance; by varying this even one or two inches 16-candle gas may give the effect of only 14, and *vice versâ*. The weight and quality of the candle must be most accurately ascertained. It is not uncommon to obtain varying results from different parts, even of the same candle, from slight variations of density only; even a perceptible per-centage of difference has been observed from a difference in the manufacture of the wicks—plaited, strongly twisted, or otherwise. The pressure of the gas also must be absolutely uniform; as an increase or diminution will produce an immediate variation of light. And lastly, the observation being conducted by the human eye, the difference of the power of vision possessed by various experimenters has a marked effect on the records.

All these points have, however, been carefully considered by scientific men, and a photometric apparatus has been designed in which every possible precaution has been taken to ensure accuracy. In some instances three or more arms duly graduated have been affixed to a central light, which is provided with an automatic apparatus for weighing the candle both before and after the experiment, conducted by a timepiece recording each second accurately by a dead-beat arrangement, the various operators, one to each arm, thus having a mutual check upon the results obtained.

When we consider the magnitude of the interests involved, the tens of thousands, nay, hundreds of thousands of pounds expended per annum in gas, and that by Act of Parliament, where in force, the companies are bound to produce gas of a certain quality, it is evident that it is of the greatest importance to obtain an unquestionably correct result.

Gas legislation is immensely voluminous: we can only allude, as the basis of most proceedings under this head, to the "Sale of Gas Act" of 1859. But the operation of this act being only permissive, it has been adopted by the City of London, one or two counties, and a few towns and districts, about fifty in number; the quality of gas elsewhere being subject only to the conditions imposed on the private Acts under which the companies are constituted, and of these it may fairly be said that their name is Legion, and their stipulations infinitely various. Several amendments of this Act of 1859 have been before Parliament in successive sessions, but for all practical purposes it is still in force. Our limits, and the object of our paper, do not allow us to go into the question of its working machinery—*i.e.*, constituted authorities, method of adoption, which, as we have said, is permissive—appointment and duties of inspectors—all points exceedingly interesting to parties concerned.

Going further, the question of the quality of gas, and the methods of testing it, the operation of the photometer may be taken as mechanical only; but it is possible, by means of chemical analysis, to arrive at far more accurate results: as, however, the experiments necessary require scientific knowledge of a high class, and also expensive apparatus, we may content ourselves by indicating the impurities that may thus be discovered, and some of the means employed.

It is of paramount importance that no admixture of atmospheric air should be allowed. Samples of the gas to be tested are therefore collected by means of a mercury trough into small gas receivers called eudiometers, and submitted to various chemical combinations. For estimating the amount of carbonic acid, caustic potash may be employed, and subsequently of oxygen with pyrogallic acid, and by a sequence of delicate operations the proportions of light carburetted hydrogen, carbonic oxide, hydrogen, and nitrogen can be successively ascertained; these operations, however, being strictly the domain of the laboratory, do not fall within the scope of these papers, though their scientific importance is undoubted.

We will here give the results of some experiments conducted by gentlemen whose names are well known in connection with the subject as to the comparative illuminating power and cost of gas as burnt through different descriptions of burners, and also as compared with other methods of lighting.

1. SERIES OF EXPERIMENTS BY DR. FYFE, COMPARING DIFFERENT BURNERS.

BURNER.	Consumption per hour.	Light given.	Illuminating power per foot of gas burnt.
Jet 5″ high . . .	1·0	1·0	1·0
Small fish-tail .	1·98	2·89	1·45
Large ditto . .	2·60	4·0	1·53
Small bat's-wing .	3 0	4·40	1·46
Large ditto . .	4·60	8·40	1·87
Argand of 40 holes .	4·50	7·84	1·74

These experiments were all made with cannel gas.

2. EXPERIMENTS SHOWING THE COMPARATIVE COST OF DIFFERENT LIGHTING MATERIALS, THE SAME AMOUNT OF LIGHT BEING OBTAINED IN EACH CASE.

	s.	d.
Spermaceti candles	6	8
Paraffin ditto	3	10
Tallow ditto	2	8
Sperm oil	1	10
Gas	0	4½

There is a popular impression sometimes prevalent that gas is unwholesome: the following table details experiments in which flames of equal power, photometrically ascertained, were placed in an exhausted receiver constructed for the purpose—the time at which the light became extinguished for want of oxygen giving a comparative figure from which some idea may be formed of their effect upon the atmosphere of an ordinary room:—

Cannel gas, 28 candle power,	burned for	152	minutes.
Coal gas, 13 candle power .	„	98	„
Spermaceti candles . . .	„	83	„
Wax candles	„	79	„
Sperm oil	„	76	„
Tallow	„	75	„
Colza oil	„	71	„

Cannel gas we have now alluded to almost for the first time. The quality of the coal from which it is made has the peculiar property of producing a gas of much greater illuminating power than ordinary commercial coal gas. A glance at the table last quoted will give some idea of its comparative purity; but at the same time it should be stated that the cost of its production is greater in almost a similar proportion. It has been sometimes used mixed in certain proportions with common gas with good results. In cases where private gas-works are erected it may be highly recommended for some special purpose—*e.g.*, for delicate manufactures, where the *quality* of the light is of more importance than its cost; also for situations where it is of importance that the products of combustion shall be as free as possible from deleterious elements. Picture galleries may be mentioned as an instance.

To burn it with advantage it requires special adaptations of burners and pressure different from those in ordinary use, as if consumed under the same conditions as ordinary coal gas a large proportion of its singularly powerful *lighting* qualities are wasted. Our space will not allow us to go into detail upon these points, which, indeed, are scarcely included within the range of domestic engineering, as, except for a factory, a large mansion in the country, or somewhat similarly extensive requirements, private gas-works are rarely required. In a subsequent paper, however, on the special subject of private gas-works, we shall probably give some idea of how its advantages can be made available, and of the various modifications of detail required for its profitable consumption.

At some future day we have no doubt that the progress of discovery and experiment will provide us with a gas made from petroleum, which in cleanliness of burning and lighting power will far exceed any gas at present in the market. This, however, is only a speculative notion. As a matter of business nothing of the kind has yet been developed to the point of commercial success, though the experiments made with this special end in view have been very numerous.

OPTICAL INSTRUMENTS.—VIII.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLE LENSES.

Their Form.—The lenses employed for correcting defective vision are of two types—the *converging*, which bring parallel rays to a focal point, and the *diverging*, which cause parallel rays to turn outwards from the axis of the lens.

The converging include the *bi-convex*, A (Fig. 15), the *plano-convex*, B, and the *concavo-convex* or *positive meniscus*, C (with shorter radius of the convex surface); the diverging, the *bi-concave*, D, the *plano-concave*, E, and the *convex-concave* or *negative meniscus*, F (with shorter radius of the concave surface). As the plano-convex and the plano-concave have, for equal degrees of power, the greatest aberration, they are least suited for spectacle glasses. To the menisci Wollaston attributed the advantage that the images suffer less when the observer looks obliquely (from the axis) through them, so that the eyes can move with a greater angular range behind such glasses, hence they are termed *periscopic* (from περισκοπειν, "to look around"); but Brewster, while allowing their value in a crowded city, in warning us of the oblique approach of objects, asserts that menisci decidedly give more imperfect vision than the ordinary form employed for spectacles, as they increase both the aberration of figure and colour.* Under certain conditions the periscopic form is liable to produce disturbance, by reflection on the concave surface turned towards the eye of the wearer. It is, therefore, on optical grounds, rather than from the fact that periscopic lenses are somewhat more expensive, that preference is usually given to bi-convex and bi-concave spectacle glasses. With these we can see satisfactorily in an oblique direction unless the power is very high; and when strong glasses are required the periscopic form entails the disadvantage of a greater weight of glass; so there is ample reason for not assenting to that unconditional preference for the periscopic lens which some surgeons and opticians profess.

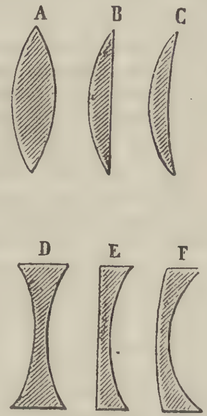


Fig. 15.


Fig. 16.

Material employed for Spectacle Glasses.—Rock-crystal and glass are the materials employed in the construction of spectacle lenses. The former is usually called by the trade pebble, or Brazilian pebble, being a natural crystal, the samples best suited for optical purposes being imported from the Brazils. As it is of equal density throughout its mass, very clear, extremely hard, takes a very high polish, and is cooler than glass, it is usually selected for the best class of spectacles, for it is important that spectacle lenses should be colourless, of equal transparency throughout, be free from striæ, blebs, etc., and have a high polish, which shall not be readily deteriorated by wear. Next in value as meeting these requirements is flint glass; but as crystal and flint glass possess a high dispersive power, crown glass, though softer and so much more liable to injury, is preferable for the construction of "strong glasses," especially of concave glasses. The cheapness of crown glass compensates for its deteriorating quality, for if spectacle lenses of this material become scratched through constant wiping or being laid carelessly about, their low price makes it easy for those of limited means to replace them. A glass dulled by fine scratches over its surface should be banished from its frame, as it tends to strain the sight of the wearer.

It is very important that the optician should be readily able to distinguish a pebble from a glass lens; also whether a pebble is of good optical character, or has been improperly cut. We may distinguish between the two, first, by determining the hardness, for rock-crystal, being considerably harder than glass, will scratch it; or by drawing the edge of the sample under trial briskly over a file it will emit sparks and not yield, while glass, on the contrary, will break down into fine powdery particles. Again, on applying samples of glass and pebble to the tongue, the latter will prove to be much colder than the other; the experienced will even detect this by the touch of the finger only. But these tests do not tell the optician all he wants to know, and the tourmaline polariscope gives the desired information in the simplest and readiest manner. This instrument consists of two thin slices of hair-brown tourmaline, cut parallel to the longer axis of the crystal, fitted in corks, and mounted in rotating tubes that face each other, which are supported by two spring blades, attached to a handle, in such a manner that a lens, etc., can be placed and held between the two pieces of tourmaline, as shown in Fig. 16. On rotating one of the crystals two positions will be found, one in which the colour of the tourmaline is apparent, with perfect transparency; the other when the crystals stand at right angles to this position, and the field of view is perfectly obscured. If now we introduce a lens of *glass* between the tourmalines (without disturbing their position), the field will still appear opaque, and *any glass lens* will give the same result,* and so indicate the characteristics of the material. If we now replace the glass with *a properly-made rock-crystal lens* the transparency of the field of view *will be restored*, but will be quite free from colour (the tint of the tourmalines allowed for); if, on testing other pebble lenses, prismatic tints, rings, or bands appear, we learn that the material *is* rock-crystal, but that it has not been cut with proper regard to the optical and crystallographic properties of rock-crystal (which will be hereafter described under Apparatus for the Polarisation of Light). Brazil pebbles are imported in rough blocks, but are really more or less defaced or water-worn crystals of the purest quartz. These are cut on a slitting-wheel, by the aid of diamond powder, into slabs or pieces of the size required; but if cut in other directions than parallel to the longer axis of the rock-crystal, tints of colour of greater or less intensity will appear in the lens; and if a slice were cut at right angles to the axis of the rock-crystal, a series of well-defined prismatically-coloured rings would appear in the lens, which would indicate its unfitness for a spectacle lens; for though these colours would not be apparent to the wearer, it would possess refractive properties that would tease the eyes, for pebble is a double refractive body, and if sliced in certain directions, through ignorance, carelessness, or indifference to conscientious workmanship, two objects instead of one are seen. Such lenses, together with those that possess wavy appearances, bubbles, or other defects, are technically called "*wasters*," and, unfortunately, are not unfrequently met with. No respectable optician would knowingly admit such refuse into his stock.

The process of working single and achromatic lenses will be described in a separate article.

As spectacle lenses are of universal and daily requirement, they are now, as a matter of necessity, nearly always produced in quantity by the aid of machinery; though, as a rule, preference is to be given to lenses carefully worked by hand, under the keen eye of a skilful workman, who brings brain and touch to detect all defects of form, centering, and polish.

To determine the Focal Length of Lenses.—It is essential that the optician should have a ready method for determining the focal length of lenses, not only of samples in stock, but of those brought by customers in their spectacle-frames, which they require to be matched or replaced with others of higher power. The usual method followed in the shops in regard to convex lenses is to throw the image of the window-frame formed by the lens on to a sheet of white paper placed against the wall in a dark corner, and then (after moving the lens to and fro till perfect definition of the window-bars is attained) to note with a rule the distance in inches between the paper and the lens.

* The difference in definition between a periscopic and a convex lens (both being of equal focus and diameter) should be noted by projecting the image of a candle-flame on to a sheet of paper placed in a dark room, the two lenses being held edge to edge. The image from the periscopic lens will be surrounded by a dazzling halo.

* Unless it be purposely *unannealed*—a thing not likely to be met with in practice—in which case coloured rings, etc., would appear, intersected by a black cross. Such glass would be unfit for spectacle lenses.

Or the inverted image of a candle (placed at some feet distance from the wall) is noted in the same manner; or, better still, if it were not that it is not always available, the image of the sun, or, as it is termed, the *solar focus*, may be employed. But it must be observed that these methods only give the value approximately; and for the reason given in the foot-note at page 111, Vol. I., the object selected (whether window-frame, perforated zinc, or candle) should always be placed *at a fixed or standard distance from the lens under trial* of at least 18 feet, so as to deal with what are practically parallel rays. The image being then focussed on a screen that *moves away from the lens*, the intervening distance or focal length is measured by a tape or wooden scale. In communications between customer and optician as to a lens of a required focus, say to replace a broken glass and pair with the remaining one, the method followed for determining the focus and the distance of the window or candle from the wall (or lens) should be ascertained to avoid error, for it will be found that the focus obtained by using a near and then a distant object will not give identical results. As it is not always possible or convenient to obtain a range of from 18 to 20 feet for the method of testing just described, a simple and better method is to use as an object two lines ruled parallel on a sheet of paper, and then view this with the lens to be tested, held at about a foot distant from the eye, and so far from the paper that both lines can be accurately seen. We now place the standard trial-glasses of known focus in succession beside this, in the same plane, with the edges touching and the centres in a line, till we find the number that gives an image of equal magnitude. When the two lines appear continuous through both lenses, the number on the trial-glass will indicate the focal length of the lens under examination. On the other hand, should the lines appear disjointed, thus, , then the standard lens does not match the glass under trial, and another must be sought. By thus trying with what trial-glass a lens agrees in magnifying or diminishing power, we can determine the focal length not only of convexes but also of concaves. The most common method of ascertaining the focal length of concaves is to place them in contact with the surface of a convex lens that will best fit the concavity of one face. When this is accurately done the power of both lenses will be neutralised, for we convert the conjoined lenses into what is equivalent to a meniscus of equal curvatures; in which case, the two surfaces being parallel, all lenticular properties are wanting (see Fig. 15): and on holding them in contact between the finger and thumb, and moving them to and fro at some distance before the eye, an object seen through the pair will appear fixed, equal, and of the natural size, and the known focal length of the convex will give the value of the concave. Should the convex, however, not be of exactly the same focal value as the concave lens under trial, then the objects observed will appear to have a tremulous motion, or larger or smaller than they really are, and the proper neutralising lens must be sought. When we have no standard trial-glasses of known focus at hand wherewith to determine the power of a concave glass, we may ascertain its focal length approximately by treating it as a concave mirror. Reflect the image of a bright flame on to a sheet of white paper, and when well defined, measure the distance between the centre of the concave lens and the screen, and so obtain a direct reading. The focal lengths of convex and concave lenses may also be accurately and conveniently ascertained by Dollond's focimeter, for by this instrument we ensure a trial under conditions that are invariably the same.

Dollond's *focimeter*, as improved by Phelps, consists of a small telescope, specially adjusted for the purpose required, mounted on a long square bar of wood 5 feet in length; this is graduated up to 48 inches down the centre of the bar, the zero point of the scale corresponding with the plane of the object-glass. On one side a comparative scale corresponding to the French standard is engraved, on the other the Prussian scale; so that we can at once determine any discrepancies as to lenses that have come from foreign sources, and been marked accordingly in French or Prussian inches, or for use in supplying glasses ordered by surgeons who employ foreign trial-cases. Over the bar traverses a stage that carries the object to be focussed. The lens under trial, if a convex, is held immediately in front of the object-glass of the telescope with one hand, while the test-object is moved to and fro with the other till it is distinctly defined. The reading is then observed through a slot in the traversing stage that corresponds to the plane of the test-object.

When concave glasses are to be tried, a brass cap fitted with a correcting lens suited for focal lengths of from 1 to 8 inches is fitted in front of the object-glass. The concave is then tested in the same manner as previously described. Should it prove above 8 inches in focus, the correcting cap is replaced with another suited for a range of from 9 to 14 inches, which comprises the usual range employed in England.

At page 307, Vol. I., of THE TECHNICAL EDUCATOR I have enumerated the glasses supplied in the German trial-cases, and also the series usually furnished in the set of English "convex triers," viz., 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 24, 30, 36, 48, which numbers express the focal lengths of the convex lenses inserted in the frames. The set of English "concave triers" usually includes a series numbered from 1 to 14. Such numbers *should* indicate negative focal lengths corresponding to the positive focal lengths of the convex series, for it is the only standard that is scientifically correct and admitting of universal application, for the reason that while all double-convex lenses are worked *in* a concave tool, the curve of which has a radius equivalent to the focal length of the *double-convex* lens it produces, all concave lenses are worked *on* a convex tool, the curve of which also has a radius equivalent to the focal length of the *double-concave* it produces. Thus, a concave tool of 7 inches radius would be used to work the two surfaces of a double-convex lens of 7 inches focus, and a convex tool of 7 inches radius to work the two surfaces of a *double-concave* lens of 7 inches focus. By following this method of making the numbers in the trial-cases, and on the lenses supplied, represent the focal lengths of concave as well as convex lenses, we have a ready means of determining the focus of concaves as previously described, wherein the concave curves neutralise the convex curves, and reduce the combination of two lenses of the same foci to the optical value of a piece of glass with *parallel* faces, though the surfaces are curved, as shown in Fig. 15 B, and still more strikingly shown in Fig. 15 E, which represent a plano-convex and a plano-concave, *each* of 14 inches focal length, made from the same tools of 7 inches radii, wherein the perfect parallelism produced by the combination of the two lenses is palpable. Unfortunately, this simple system, the common-sense and scientific value of which is self-evident, has not always been followed; and the "shop element," in the interest of quack oculists, has led to the introduction of arbitrary numbers and scales, that could only have been adopted to "fog" those who were not in "the favoured circle." Thus, according to one arbitrary system (as a sample of many others), a concave *numbered* 1 corresponded to a 24-inch convex; No. 2 concave to a 21-inch convex; No. 3 concave to an 18-inch convex, and so on; instead of 24 concave = 24 convex, 22 concave = 22 convex, 18 concave = 18 convex, and so on. So that if a patient went to any other optican but that recommended by the oculist he would not obtain the glasses absolutely required. Again, I have before me an arbitrary scale of German invention that does not correspond to the standard of any nation. It runs in the following fashion:—

Up to No. 7 it corresponds exactly inch for inch with the English scale; then—for convex numbers—

8	*nearly*	corresponds	with our	$8\frac{1}{2}$	inches.
9	,,	,,	,,	$9\frac{1}{2}$	,,
10	,,	,,	,,	$10\frac{1}{2}$	,,
12	,,	,,	,,	13	,,
14	,,	,,	,,	$13\frac{3}{8}$	,,
16	,,	,,	,,	17	,,
18	,,	,,	,,	19	,,
20	,,	,,	,,	22	,,
22	,,	,,	,,	25	,,
24	,,	,,	,,	28	,,
30	,,	,,	,,	35	,,
36	,,	,,	,,	$44\frac{1}{2}$	,,

No. 30 in this scale is the zero point for the concave series; and going upwards—

No.	1 = 24	of the	German	scale.
,,	2 = 20	,,	,,	,,
,,	3 = 16	,,	,,	,,
,,	4 = 14	,,	,,	,,
,,	5 = 12	,,	,,	,,
,,	6 = 10	,,	,,	,,
,,	7 = 9	,,	,,	,,

No. 8 =	8 of the German scale.			
„ 9 =	7	„	„	„
„ 10 =	6	„	„	„
„ 11 =	5	„	„	„
„ 12 =	$4\frac{1}{2}$	„	„	„
„ 13 =	4	„	„	„

I need hardly say that no respectable optician should countenance any such arbitrary or irregular scales, palpably devised for the purpose of "fogging" the uninitiated; and any "medical oculist" who adopted such a scale could not feel aggrieved if his claim to a scientific position were disputed, and he were branded with the title of "Quack," for no true disciple of Science would ever give countenance to mystery.

I must here give a caution as to the discrepancies which may arise from the use of trial-cases furnished from different countries, any errors arising from which source I hope to correct by placing before the readers of THE TECHNICAL EDUCATOR, in a future number, a comparative series of measures of all nations, which would possess great value for many scientific and artistic purposes. The optician should therefore always be particular to ascertain, when spectacles are ordered for a patient by an ophthalmic surgeon, whether he adopts an English, French, or German series of trial-glasses. Through this multiplicity of standards great confusion and annoyance have been caused both to opticians, patients, and surgeons. Undoubtedly, it would be an advantage for all scientific purposes if the French scale founded on the metre adopted by the Paris Board of Longitude were followed, as being the only standard established on a scientific basis, our own and all other measures of length, etc., being arbitrary.

SPECTACLE-FRAMES.

The Frames.—Formerly the spectacle lenses were supported in heavy frames of tortoiseshell, silver, or gold, but the two first are now seldom employed, tempered steel or gold having superseded such antiquities, shell-work being only used for eye-glasses and spring-folders. As there are many qualities of material used in the manufacture of blue steel spectacle-frames, varying from mere soft iron, or iron fronts with steel sides, to the very best quality wrought out of steel plate, particular attention should be given to the lightness and temper of the work, for it is well to remember that a pound of pig-iron, which costs but a penny, can be wrought into watch-springs of the value of £240! Some so-called steel frames will be found to bend like a piece of bottle-wire, but the genuine article will always keep its shape. Provincial-made frames are produced in quantity, and seldom possess that finished workmanship which characterises the best London-made spectacle-frames. The price of a frame, then, depends upon the quality of its material and the finish of its workmanship. In a well-made frame the side-pieces should turn out from the hinge as firm and straight as the blade of a well-made penknife would do from its handle, for any amount of play in the joint should only exist after long wear and tear; and there should be no perception of anything like a grating, rasping action when the side-piece is being worked backwards and forwards in its joint. Should the side be lengthened by a second piece, working on a "turn-pin," the two should fold neatly and closely together, and the turn-pin should hold them at any position in which they should be placed in relation to each other. When the side-pieces are turned down they should protect, not scratch against the glasses, which, when packed away, should be guarded on their exposed side by the concave form of the spectacle-case, especially for convexes, which are more palpably exposed to injury by scratching than the indented surfaces of concaves.

It is a mere matter of fancy or fashion whether steel frames are blue or "straw colour," either tint being produced at will in the process of tempering. The same may be said with regard to the shape of the lens-rims. Old-fashioned spectacles were made with "round eyes," but as we secure a sufficient range of observation with the modern oval-shaped glasses, without teasing the eye with the excess of light the antiquated round eyes admitted, the latter are now seldom employed but for exceptional purposes, for they are not only clumsier in appearance, but also entail a greater and unnecessary weight.

Next to the proper selection of the glasses it is a matter of the greatest importance that the frames should accurately fit the face of the wearer. And here I may observe that the majority of people fail to notice the importance of having such an important organ as the eye accurately measured and fitted; yet persons who would never dream of purchasing a pair of ready-made boots, or of putting on a suit of slop-shop clothes, do not hesitate about taking the first pair of spectacles that are given to them from the stores of jewellers, toy-merchants, and other dealers who dabble in optical goods; who, they must know, if they gave a moment's thought to the matter, have no pretensions to optical knowledge. Every optician must have met with a middle-aged housekeeper who has adopted a pair of her aged master's cast-off spectacles, or a needy clerk who has secured, as he thinks, "a great bargain" at a pawnbroker's, and both of these types wonder why their eyes are fatigued and the sight deteriorated since they began to wear such glasses.

The main points of construction are that one glass should not stand higher than the other; that the centre of each glass should coincide with the centre of each pupil (or otherwise they will act as prisms, and tend to create a squint), or but slightly less apart than the pupils for near-sighted spectacles; that the bridge or nose-piece should be flattened or arched out according to the shape of the wearer's nose and face, so as to allow of distinct vision for distant objects over the top edge of the frame, and for concaves being placed nearer to the eye than is necessary or advisable for convexes; that the sides should neither press the head too tightly or too lightly, but just secure a comfortable grasp; and that "the front" is not so short for the wearer's face that he looks upon the outer, or so long that he looks upon the inner edge of the glass or metal rim.

If we apply these rules to the ever-varying proportions of the human face, it may be gleaned that when an accurately-constructed pair of spectacles is desired, and a few days can be allowed to the optician, it is better to make them specially for each patient rather than take a frame from stock that nearest meets the desired requirements.

The mean distance between the centres of the pupils of the eyes is on an average about $2\frac{1}{2}$ inches. The exact distance for each person may be measured by means of the points of a pair of compasses, guarded with two small black beads, adjusted till the points correspond to the centres of the pupils, while the person looks at a distant object to prevent squinting, which would give a deceptive gauge. The compass-points should be pressed on paper on which the patient's name, with all other details for constructing the frames, should be filled in.

The length of the bridge varies from 1 inch to $1\frac{3}{10}$ inches. The longer diameter of an oval rim should be about $1\frac{1}{10}$ inches, the shorter diameter about $\frac{9}{10}$ inch. The joint or knuckle varies from $\frac{3}{10}$ to $\frac{4}{10}$ inch.

I may here remark that the knack which some persons have of placing the bridge on the very tip of the nose should be discontinued, as injurious and absurd. On the other hand, pressing the glasses *too* close to the eyes may irritate and inflame the eyelids, or at least the glasses will be dimmed by moisture from frequent contact with the eyelashes. The front should be perfectly rigid, for if it yields the glasses lose their parallelism with the eyes, when vision will become disturbed and the sight distressed. The first joint or side-piece should be $4\frac{1}{2}$ inches long, and so curved that only the last half-inch touches the head. The second joint or piece beyond the turn-pin should be $2\frac{3}{4}$ inches long. Whether one or two joints are employed, the ends should terminate in a loop, which is filled up with sealing-wax.

The glasses as sent out from the grinding tool are round, and they are clipped into an oval form of the exact size of the opening in the frames by means of a pair of flat-bladed nippers, which crunch off the superfluous glass bit by bit; and the edges are ground even, and smooth, and angular in a small grindstone, supported in a water-trough. The small screws in the knuckles are removed to facilitate the insertion of the lenses so edged. The proper centreing of the glasses in their frames is effected during the process of shaping with the nipping tool.

PRACTICAL PERSPECTIVE.—XI.

FIGS. 52, 53, 54, 55.—The subject of this lesson has already, in Fig. 28, occupied the attention of the student; but in the former case the table was placed so that one of its sides was on the picture-line, the length being parallel to the picture-plane; whilst in the present study the sides recede at certain angles.

Fig. 52 is the plan of the table placed at the required angles in relation to a straight line. Fig. 53 is the side elevation—that is, the exact geometrical figure which would stand on the line A C of the plan; the points which would correspond are similarly lettered. Fig. 54 is the end elevation, or that which would stand on the line A B.

quired that the nearest angle shall be situated, draw lines to the vanishing-points.

From A set off A B and A C′ equal to the sides of the table, taken from the plan (Fig. 52).

From B and C′ draw lines to the measuring-points, cutting A VP1 and A VP2 in *b* and *c*.

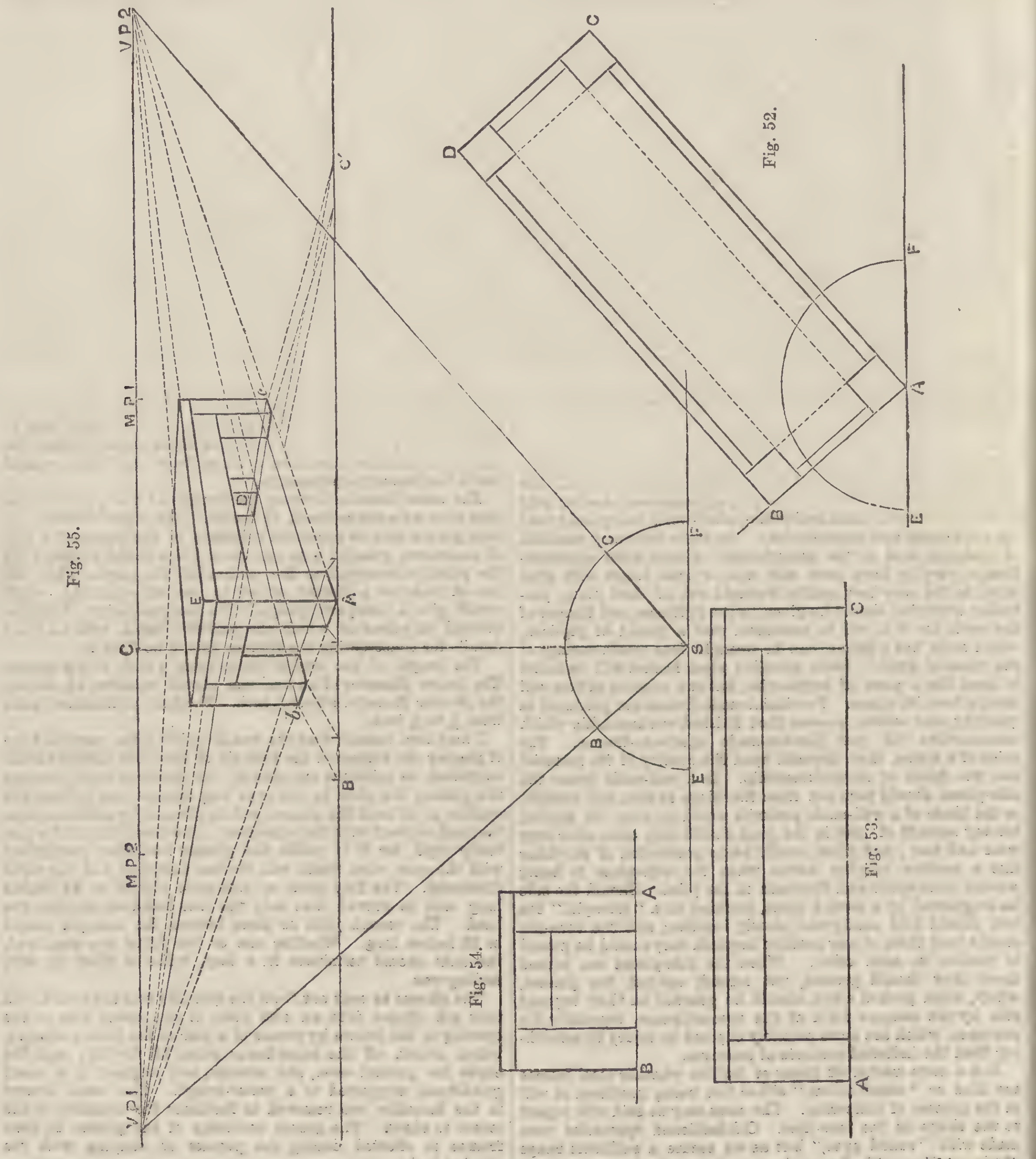


Fig. 55.

Fig. 52.

Fig. 54.

Fig. 53.

We now proceed to work out the projection from these given data (Fig. 55).

Having drawn the picture-line, the horizontal line, and line of direction, find the vanishing-points—that is, construct at the station-point S, angles B S E and C S F, similar to the angles B A E and C A F in the plan. Produce these lines until they meet the horizontal line in VP1 and VP2, and from these points, as shown in former lessons, find the measuring-points.

Now from A on the picture-line, the point at which it is re-

From *b* and *c* draw lines to the opposite vanishing-points, cutting each other in D, and this will complete the boundary of the plan.

On each side of A set off the thickness of the legs, measured from the plan or either of the elevations, and on the inner side of B and of C′ set off the same width; and from each of these points, as before, draw lines—first to the measuring-points, and then to the vanishing-points; and these will complete the plan.

The height E having been marked on the perpendicular A, the rest of the figure will be worked as shown in several previous lessons.

Exercise 43.

Put into perspective the table shown in the last study, when it is placed at a given distance—say 10 feet within the picture, the height of the spectator in Fig. 55 being taken as 5 feet.

Fig. 56.—This study is a further development of the previous one, and shows a table the top of which projects beyond the plane of the legs and framing. Having drawn the preliminary lines—the plan and elevations of the object according to the system shown in the last study—and having found the vanishing-points and measuring-points according to the angles at which the sides of the object are supposed to recede, project the boundary of the plan. This done, set off from A, and also within the points on the picture-line from which the lines were drawn to the measuring-points, the widths, first of the projection of the top of the table beyond the plane of the legs, viz., B and C, and secondly, the thickness of the legs, viz., D and E.

From all of these points draw lines, first to the measuring-points, and then to the vanishing-points. The process is, in fact, a repetition of the last figure, excepting that there is a double set of lines employed.

It will now be observed that whilst in the last study (Fig. 55) the front leg stood on the square corresponding with A *b a c* in the present figure, it is not so in this instance, for the legs stand back, although the angle of the top of the table would in reality touch the picture-plane. The leg, therefore, stands on the figure *a e f d*, and the other three legs stand upon the corresponding lozenge-formed figures in the angles of the inner figure.

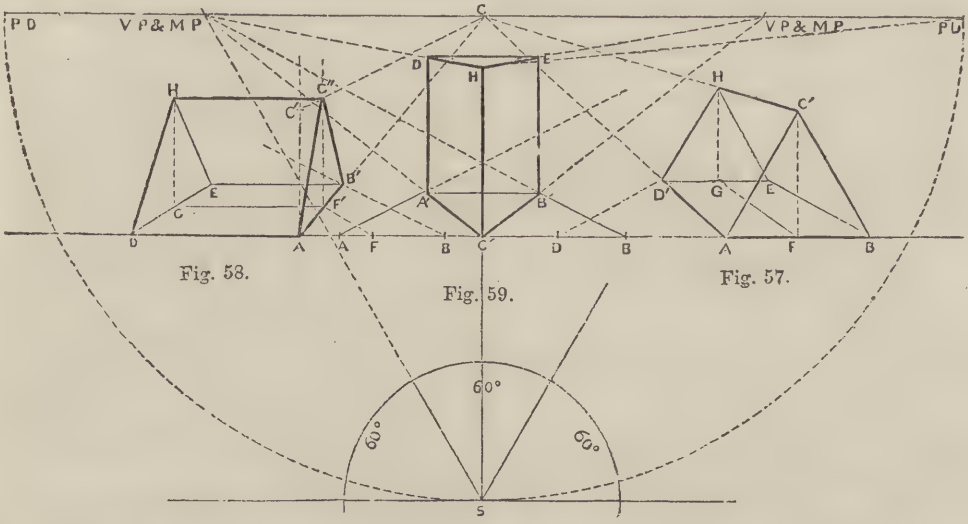


Fig. 58. Fig. 59. Fig. 57.

Having completed the plan, draw a perpendicular at A, and on this mark the points F and G for the full height and the thickness of the top of the table; from both of these points draw lines to the vanishing-points (not shown in this figure).

From H and I, the two distant angles of the plan, draw perpendiculars, cutting the lines drawn from F and G to the vanishing-points in J K and L M; these will give the distant angles of the top of the table, for it will be clear that these will be exactly over the angles of the plan H and I, as F and G are immediately over the nearest angle A.

From J and L draw lines to the opposite vanishing-points, which, cutting each other in N, will complete the top of the table.

Now draw the perpendiculars *e*, *a*, and *d* for the nearest leg, and the *two* outer perpendiculars of the legs at H and I, leaving

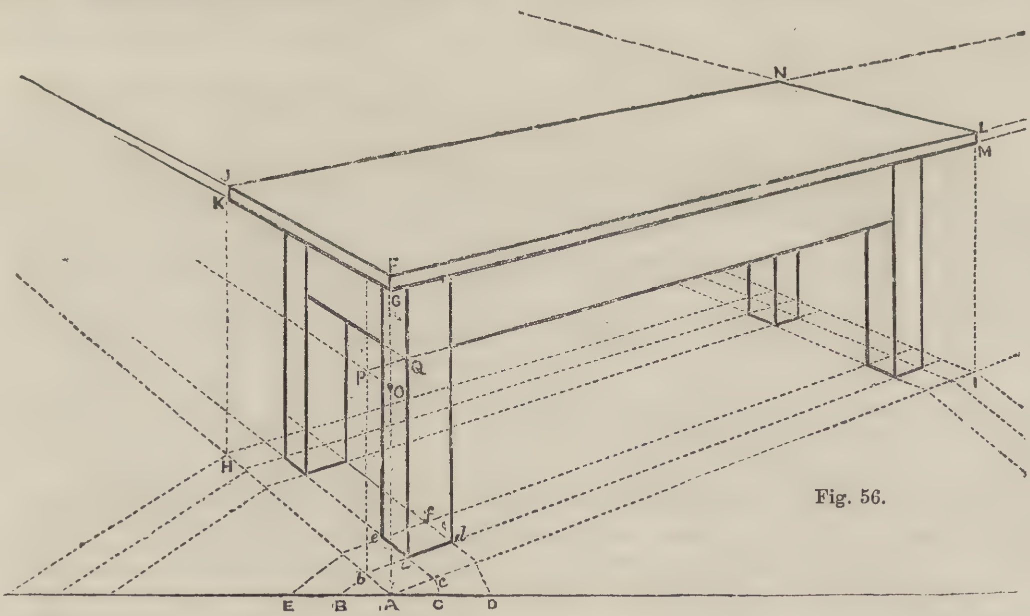


Fig. 56.

the third perpendicular of each of these, and also the whole of the distant fourth leg for the present.

It is now time that the framing under the plate of the table should be drawn. This is not on the same plane as the edge of the table, but forms in most cases a portion of the plane of the legs, whilst in others it is mortised so as to leave the legs a little more forward than the surface of the framing. For the sake of simplicity, the former case is assumed. It becomes necessary, therefore, in the first place to mark its true height in the foreground, and then carry it back.

On the perpendicular A mark the real height of the bottom line of the framing—viz., O; and from *b* erect a perpendicular.

Now from O draw a line to the vanishing-point, cutting the perpendicular *b* in P.

On examining the plan, it will be seen that *b* is on the same plane as the point *a*, and therefore the perpendiculars *b* and *a* are on the same plane; hence a line drawn from P to the same point to which the line from *b* is vanishing must pass through the perpendicular on *a* in the point Q, and this is then the perspective height of the framing.

From Q draw lines to the vanishing-points, and then the third perpendiculars of the legs, and the distant leg, may be drawn, thus completing the object.

EXERCISE 44.

The height of the table in Fig. 56 being taken at 2 feet 6 inches, put the same object into perspective when standing at the same angle as in the last study, but at 6 feet within the picture.

EXERCISE 45.

Put into perspective the structure represented in Fig 43, when its sides recede from the picture at 40° and 50°, when its nearest angle is at 3 feet on the left of the spectator, 10 feet within the picture, the height of the spectator in Fig. 43 being taken at 6 feet.

The subject of the next study is a prism formed of three equal sides.

In Fig. 57 the object is placed so that the end is parallel to the plane of the picture, and in this view it will be easily understood that the end elevation will form an equilateral triangle.

Having, then, drawn the horizontal line at the required height above the picture-line, and having fixed the centre of the picture and the points of distance, draw the equilateral triangle A B C′ at the given distance on the right (or left, as the case may be) of the spectator.

From A and B draw lines to the centre of the picture, for it will be clear that, as the equilateral triangle is the section of the prism taken at right angles to its edges, when the triangular end is parallel to the plane of the picture, the edges of the prism will be at right angles to it, and will therefore converge to the centre of the picture.

Now from A set off on the picture-line A D, representing the true length of the prism, and from D draw a line to the point of distance, cutting A C in D′.

From D′ draw a horizontal line, D′ E, and it will be clear that this line, D′ E, is the perspective rendering of the length A B when at a distance within the picture equal to A D (see Fig. 11, Vol. I., p. 333); and it will also be obvious that as the distant end of the prism is in this case supposed to be parallel to the near one, it will, although diminished by distance, be an equilateral triangle, the base of which will be the line D′ E; and therefore, in the present case, it would be sufficient to construct this equilateral triangle, and draw a line uniting the apex of the first triangle to that of the second one.

But this process would not, for the purpose of instruction, be a satisfactory one, as it would only be applicable when the prism is absolutely an equilateral one. The following method is therefore given because it can be used whether the section be an equilateral, isosceles, or scalene triangle.

From C′, the apex of the original triangle, drop the perpendicular C′ F.

From F draw a line to the centre of the picture, cutting D′ E in G, and at G erect a perpendicular.

Now from C′ draw a line to the centre of the picture, cutting the perpendicular G in H. Then it will be clear that G H is the perspective height of the perpendicular F C′ when at the given distance within the picture (as shown in Fig. 8, Vol. I., page 333).

The point H is then the apex of the distant triangle, therefore draw D′ H and E H, which will complete the projection of the prism, and it will be seen that C′ F G H is a vertical section through the upper edge of the prism, dividing the whole object into two prisms, the ends of each of which are the right-angled triangles A F C′, D′ G H and B F C′, E G H.

CHEMISTRY APPLIED TO THE ARTS.—XI.

BY GEORGE GLADSTONE, F.C.S.

SULPHURIC ACID.

SULPHURIC ACID, or as it is commonly called "oil of vitriol," is used in the arts for such a variety of purposes, that its manufacture is a large and constantly increasing one.

Some of its uses have been incidentally mentioned in previous articles of this series. It will be found mentioned in those on bleaching, dyeing, calico printing, and soda making; but besides these uses, it enters into the composition of green and blue vitriol (the sulphates of iron and copper), and alum; is used in medicine in the form of Epsom and Glauber's salts and mineral waters; and is employed in the manufacture of ether, nitric, hydrochloric and acetic acids, and in the preparation of superphosphate of lime for manure.

This acid used to be made principally from rock or native sulphur, which occurs in many volcanic districts, but principally in that of Sicily. It had all to be imported from abroad, and at times it was found difficult to obtain an adequate supply at a sufficiently reasonable price. This compelled the makers to look for other sources of supply, and now they are almost independent of Sicily, copper and iron pyrites being used instead to a very great extent.

Sulphuric acid (H_2SO_4) contains one atom of sulphur to two of hydrogen and four of oxygen; but if we burn sulphur or roast pyrites, the gas given off will be sulphurous oxide (SO_2), which does not contain sufficient oxygen. An ingredient has therefore to be found which will readily give up to the sulphur some of its oxygen. Nitrate of potash or soda is found most suitable, as either is a very cheap article, and furnishes one more atom of oxygen. Water (H_2O) completes the formula. The ingredients used in the manufacture are therefore few and simple, and hence the low price at which this most useful acid can be produced.

The process by which the ingredients are brought into combination will need, however, a detailed description. The sulphur is burnt, or the pyrites roasted, in a furnace without any admixture of fuel, because sulphur will catch fire and burn of itself at a temperature of 302° Fahrenheit; and pyrites also will decompose with evolution of heat, so as to carry on the operation continuously when once started. When sulphur is used, it is spread upon an iron plate, which has been already heated from below, whereupon it immediately takes fire and burns slowly away, the air admitted being only just what is required to maintain combustion. When pyrites, or sulphide of iron (Fe_2S_2), is to be employed, a furnace of more regular construction has to be used, as the maintenance of the heat requires more management, and there is a large bulk to deal with, only one atom of the sulphur being driven off, the other remaining in combination with the iron. The furnace having been first heated sufficiently by burning some coke in it, the charge of pyrites is inserted through a door in the upper part, and is kept constantly supplied, the roasted ore being from time to time withdrawn through a door at the bottom.

The sulphurous oxide given off in either case passes upwards through a large flue into the first chamber. In this flue are placed some saucers containing the nitrate of potash or soda, mixed with sulphur, or sometimes nitric acid alone, which in the presence of the hot fumes of sulphurous oxide is decomposed, giving off nitric oxide (NO), which passes up the flue along with the sulphurous oxide into the chamber. The chambers into which the vapours pass vary in number and size in different factories, but they are necessarily very large, as all the ingredients of the acid are brought together in the condition of gas or vapour. Thus in one establishment where 7½ tons weight of acid are produced daily, five chambers are used, having an aggregate capacity of 178,000 cubic feet. These chambers are indeed one of the principal sources of expense to the manufacturer, for sulphuric acid is of so corrosive a character, that it is difficult to find any material that is applicable

which will effectually withstand its action. The only one suitable for this purpose is lead; and it is no easy matter to build a room 80 or 100 feet long of sheet lead, which shall be thoroughly air-tight. A skeleton room has first to be constructed of open woodwork, and then lined throughout with heavy sheet lead. No solder can be used in joining the sheets together, as that would be soon eaten away by the acid, but they have to be made to overlap one another, and the space between them carefully filled in with white lead paint. Notwithstanding the greatest care, these chambers are very apt to get out of order, and they are therefore so arranged that all parts of the roof, walls, and floor can be got at from the outside for repairs.

The sulphurous and nitric oxides pass, as has been already said, up the flue into the first chamber. They will enter this near the roof; the leaden pipe connecting the first with the second chamber will be near the floor, and so on alternately throughout the series, so as to facilitate the intimate mixture of the gases with each other and the atmospheric air. In some factories, instead of having separate chambers, they have one long gallery partially divided by partitions made of sheet lead, the one partition extending from the floor upwards to near the ceiling, and the next from the ceiling downwards: this arrangement answers the same purpose of mixing together the gases in their passage through the gallery.

The nitric oxide will not, however, remain unchanged in the presence of atmospheric air, but robs the latter of some of its oxygen, and changes itself into the peroxide NO_2.

The water which is required is supplied in the form of steam. To a small boiler are connected a series of pipes, which are carried round the outside of the several chambers, and terminate in leaden pipes, which pass through the floors and walls some distance into the chambers: from these jets of steam are from time to time thrown in, which also contribute to the mechanical admixture of the gases, the position of the jets being so arranged as to produce as great a stir as possible.

But the peroxide of nitrogen cannot remain unchanged in the presence of sulphurous oxide and watery vapour, and it loses again the atom of oxygen it has already stolen from the air, which now passes in turn to the sulphurous oxide, raising that to SO_3. The sulphuric anhydride thus formed has again such an affinity for water, that it will take it up whenever present, and thus becomes converted into sulphuric acid (H_2SO_4), a thick oily liquid.

This interchange of particles is constantly going on within these leaden chambers, and the resulting acid falls down like heavy drops of rain upon the floor. As sulphuric acid will continue to absorb water in addition to the definite quantity required to complete the above formula, the amount of steam injected into the chambers should bear a certain proportion to the quantity of sulphurous oxide which has been evolved from the sulphur or pyrites. This is a matter of simple calculation. Sufficient water vapour should be supplied to reduce the acid to about a 54 per cent. solution: if it were to be made much stronger, there would be a waste of sulphurous oxide, and if much weaker, there would be a waste of nitric oxide.

When a quantity of acid of about this strength has accumulated on the floor of the chambers, it is drawn off, and has then to be distilled over, in order to raise it to the proper strength of the regular commercial acid, which should be 93 per cent. For this purpose it first passes into the concentrating pans, which are also made of sheet lead: there is generally a series of them communicating one with another, and each one slightly lower than the preceding, so that during the concentration the acid passes through the whole series. The pans have a movable covering made of sheet lead, and they rest upon plates of iron. Near the lowest pan is a furnace, the flue from which passes under the whole series, so that the flame from the furnace beats upon the iron plates on which the concentrating pans rest. Sometimes the arrangement is altered, by which a great saving in the wear and tear of the lead pans is effected. It consists in bedding them upon solid brickwork, and carrying the flue from the furnace over instead of under, so that the surface of the acid itself forms the lower side of the flue, and the nitric and sulphurous fumes are carried away through the flue with the hot air. Here any nitric and sulphurous oxide which has escaped decomposition is driven off, together with about 11 per cent. of water. As soon as the acid has thus attained a 65 per cent. strength, the operation must be stopped, as the lead would suffer if carried further, and some of the acid would be lost, sulphate of lead being formed.

In the subsequent process, vessels of glass or platinum must be used. The danger attendant on the use of the former almost compels the manufacturer to go to the expense of platinum retorts. One of these large enough to contain 20 cwt. of acid will cost about £2,500, all the joints of the platinum being soldered with gold, the only metal available which will withstand the action of hot concentrated sulphuric acid.

The 65 per cent. acid is drawn from the lead pan into the platinum retort by a glass syphon, and here it is gently boiled. The excess of water separates, and is drawn off by a tube, leaving the acid of the full strength required, 93 per cent.

The acid has now only to be transferred from the retort to the glass carboys, in which it is kept for sale; but as it is very hot, and would infallibly crack the glass if not first cooled, it is drawn off by a long syphon made of platinum, which is encased in a hollow tube through which a stream of cold water is made to pass constantly, so that on its passage from the retort it is sufficiently chilled to admit of its being poured with safety into the carboys. It cannot be left in the platinum retort till cool, because that would involve the extinguishing and re-lighting of the fire, and a very great waste of time, so that a greatly increased number of these expensive retorts would be required in a large factory. The object of the manufacturer is, of course, to get the largest possible amount of work out of them, by keeping them incessantly going.

Sulphuric acid is used for such a variety of purposes, that it has become a very important article of commerce, and in this country more than 100,000 tons per annum are now made, the greater part of which is consumed at home, though it is shipped to almost all parts of the world. Every 100 lb. of sulphur (or its equivalent in pyrites), with 3 lb. of nitrate of sodium, will yield about 310 lb. weight of acid; the gain in weight being due to the oxygen and hydrogen, which are abstracted from the air and water within the chambers, 150 lb. of oxygen and 56 lb. of hydrogen being necessary to complete the combination. So large an amount of air is required for the supply of this oxygen, that were it not for a continuous inflow through the pipe which also supplies the sulphurous oxide, the reduction of the oxygen from the gaseous state, and the condensation also of the watery vapour, would cause the leaden chambers to collapse—an accident not unlikely to happen upon the old system, now superseded, of burning the sulphur within a closed chamber. In the commercial acid there is a slight excess of water, rather more than counterbalancing the loss of sulphur during the process, which averages about 6 per cent.

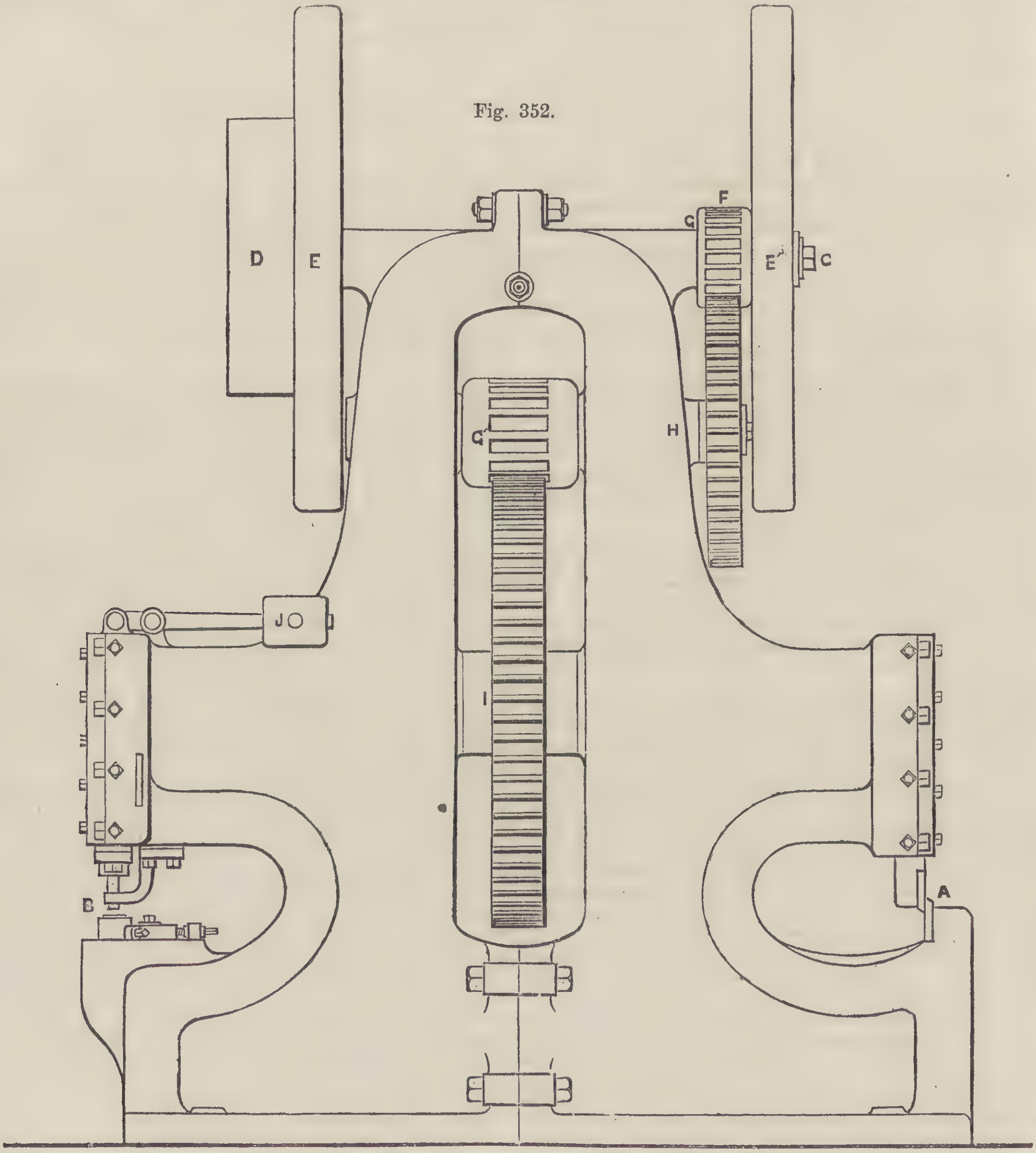
There is, however, another process of making this acid, which produces a purer article than the commercial acid, and is distinguished as the Nordhausen, or fuming oil. Sulphate of iron, or green vitriol, when heated to redness, gives off its acid without further decomposition; and advantage is taken of this circumstance by the makers. The crystals of green vitriol contain a large quantity of water in combination, all but one equivalent of which is readily driven off by calcination in an oven. The calcined article is then put into earthenware retorts, which are built into a furnace, the neck only protruding, and immediately that cloudy fumes begin to issue, a receiver containing a little pure water is attached closely to the neck of the retort. The fumes of sulphuric acid are absorbed by the water, and the process goes on until all the acid has been given off: the receiver is then removed, the retort re-charged with the calcined vitriol, and as soon as the thick fumes reappear, the receiver is again attached. At each repetition of the process, the water in the receiver absorbs more and more of the acid, until it has attained its maximum strength. It is then transferred to stone-ware jars, the stoppers of which are cemented down, in order to prevent its escaping into the air. It is a thick oily liquid of 1·9 specific gravity; and contains some excess of SO_3 uncombined with water, which, being very volatile, causes it to fume, forming with the moisture of the air a perceptible cloud. The furnaces are generally so arranged, that one source of heat will serve for the calcining ovens, and sometimes as many as sixty retorts; but the process cannot conveniently be carried on upon the great scale adopted in making the commercial acid, and the cost of the manufacture is very much greater. The strength and purity of the fuming oil render it indispensable, however, for special purposes.

TECHNICAL DRAWING.—XXXVI.

PUNCHING AND SHEARING MACHINE.

We now give, in Fig. 352, a side elevation of one of the powerful machines which are employed for cutting or punching holes in plates of iron for making boilers, girders, etc. One side of the machine, A, has shears, and the other, B, a punch, so that two sets of men may work at it if necessary. Motion is given to the upper shaft, C, by a strap to a plate of iron is inserted. Motion from the first shaft is transmitted through a second, H, to the large centre wheel, and at each end of the shaft which carries it there is a crank or eccentric, which gives motion to the sliding-blocks that carry the punch and shears. The punch may be put in or out of gear without stopping the fly-wheels; and the balance weight, J, is intended to hold it up whenever out of work, that plates of iron may readily be inserted for punching, placed in their proper position, and then the punch started.

Fig. 352.



the large pulley, D. Two heavy fly-wheels, E and E′, are keyed upon this shaft, and also a pinion, F, of singularly strong construction. In the lessons (see Vol. I., pages 349, 359) which treat of the teeth of wheels, it has been shown that in the case of small pinions the lower parts of the teeth are comparatively weak, and so if they were subjected to the heavy strain that the wheels of this machine have to endure, breakage would result, unless special arrangements be made to prevent it. Flanges, G and G′, are cast on both sides of the teeth, and give to them just the kind of support they require. The fly-wheels run at considerable speed, and their impetus overcomes the sudden resistance given to the punch B, or shears A, when

This class of tool is almost the heaviest and strongest that is made, for it has to endure a pressure of many tons suddenly applied, while the necessity of having a wide opening at the place where pressure is exerted prevents the metal offering a direct resistance to it. The illustration we have given above shows a machine of good design and strength, and excellent in the arrangement of its various parts.

DRILLING MACHINE.

Fig. 353.—This ranks with the lathe as one of the most useful tools in a workshop. The objects required in designing such a machine are to provide a vertical spindle that shall revolve at

any desired rate, and be moved up or down quickly by hand or slowly at different rates by self-acting mechanism. The lower end of this spindle must carry a drill that can be changed at pleasure.

Below this spindle there must be an adjustable table, one that will slide into any position, or rise and fall while carrying the work to be drilled, and also move aside out of the way to admit large objects under the machine.

The drill (Figs. 354 and 355) is a revolving cutter, and its object is to form circular holes in iron or other material. It is held in a chuck, as shown in the enlarged scale (Figs. 356 and 357). A small set-screw holds the steel drill in the chuck by the flattened part, so as to prevent its turning round.

These several requirements are well attained in the drilling-machine illustrated. Motion is given to the coned pulley, and by placing the strap on the different cones four varieties of speed may be given to it. A pair of bevel-wheels communicate this motion to a hollow vertical spindle, through which passes the drill-spindle, carrying chucks and drills at its lower end. On its upper end there is a hollow shaft of the same outside diameter as the drill-spindle, which has a rack upon it, and may be raised or lowered by means of a pinion inside the framing and the worm-wheel, and worm outside. For quick speed the cone-pulley is bolted to the spur-wheel beside it, and which alone is keyed to the shaft; but for slower speeds the bolt is withdrawn, and the second lower shaft driven by the cone-pulley from the pinion at the left-hand side. A similar pinion on the second shaft communicates a reduced speed to the large spur-wheel on the primary shaft, and so transmits motion to the drill-spindle. This arrangement is precisely similar to the back-gearing of a lathe. There are two cone-pulleys at the back of the machine, which give any required motion to the worm-wheel and rack that advance the drill-spindle, while a handle conveniently placed enables an attendant to move the drill-spindle up or down by hand, or put the self-acting mechanism into gear.

Below the drill-spindle there is a level table which can slide backwards or forwards, and be raised or lowered, by a similar arrangement to that which raises or lowers the drill-spindle, or may be swung round upon a vertical shaft, and fixed in any position by means of the locking-nut below. The grooves in the table are intended to receive bolt-heads and fasten anything down upon it, and the bed-plate below is provided with similar grooves for bolting down work of large dimensions.

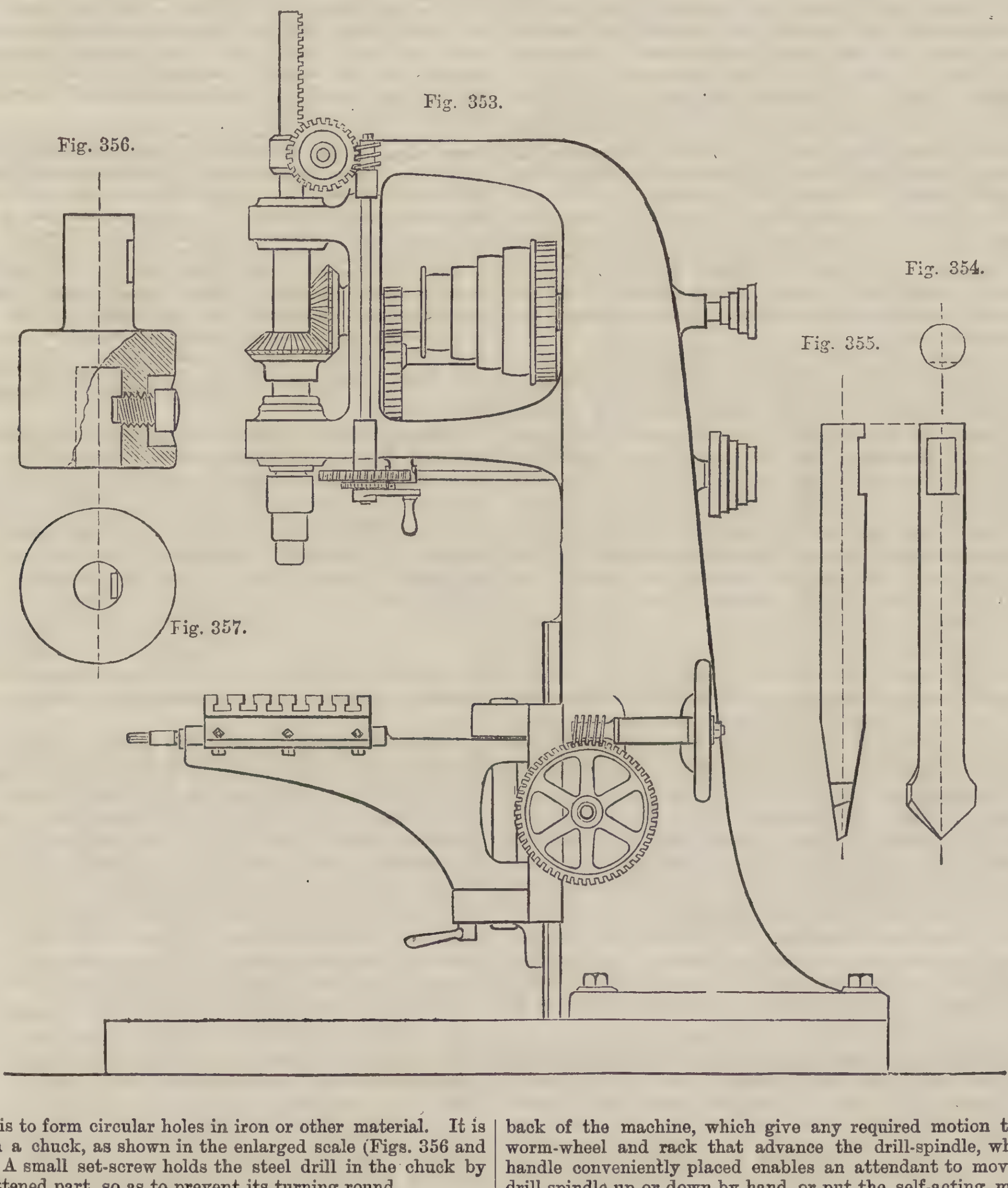


Fig. 353. Fig. 356. Fig. 357. Fig. 355. Fig. 354.

NOTABLE INVENTIONS AND INVENTORS.

XVI.—PRINCE RUPERT.

BY JOHN TIMBS.

"NOVEMBER 23rd, 1682, died of a fever and pleurisy, at his home in the Spring Garden, Rupert, Prince Palatine of the Rhine, etc., in the sixty-third year of his age" ("Historian's Guide," 1688). In these few lines was announced the death of Prince Robert Rupert, of Bavaria, whose checkered fortunes are prominent in the records of the Civil War, and who, though wanting in most of the qualities which constitute a great man, had a quick perception, and was active and energetic. His taste for military pursuits led him to take an active part in the stormy times in which he lived; but he was impetuous and indiscreet, unpopular throughout the country, and had the misfortune, says Lord Clarendon, "to be no better beloved by the king's party than he was by the Parliament." But he could readily change employments and pursuits, and to his possessing this serviceable quality may, perhaps, be attributed Rupert's atoning for his ill success in political life by becoming *a working inventor*. After his reconciliation with Charles II., Rupert took up his residence with the Elector of Mentz; and here, says Mr. Eliot Warburton, in the first leisure of his manhood, his mind reverted, with a sense of luxury, to the philosophical labours in which even his youth had taken pleasure. He now found new sources of interest in the forge, the laboratory, and the painter's studio.

It was during this lull in the active life of Rupert that he is said to have discovered or improved upon the art of engraving in mezzotinto. While immured in the Castle of Lintz, he had exercised his genius upon some etchings that still bear the above date. He was long said to have *discovered* the art of engraving in mezzotinto, reported to have been suggested to him by observing a soldier one morning rubbing off the barrel of his musket the rust which it had contracted from being exposed to the night dew. The prince perceived, on examination, that the dew had left on the surface of the steel a number of very minute holes, so as to form the resemblance of a dark engraving, part of which had been here and there already rubbed away by the soldier. Rupert immediately conceived the idea that it would be practicable to find a way of covering a plate of copper with little holes which, being inked and laid upon paper, would undoubtedly produce a black impression; while, by scraping away in different degrees such parts of the surface as might be required, the paper would be left white where there were no holes. Pursuing this thought, Rupert, after various experiments, invented a kind of steel roller, covered with points or salient teeth, which, being pressed against the copper plate, indented it in the manner he wished; and then the roughness thus occasioned had only to be scraped down where necessary in order to produce any gradation of shade that might be desired. This anecdote obtained currency from its being related by Lord Orford, in his well-known work upon the arts, as well as from the avidity with which origins of the arts are commonly set down as the results of accident. In short, it is said that Prince Rupert tried and succeeded, and thus became the inventor of mezzotinto engraving. If mezzotinto really had its origin in such circumstances as these, which is far from being improbable, they must have occurred to another rather than to Prince Rupert, since he certainly was not the inventor of the art, as we shall presently show.

The merit of the invention has been claimed by some authors for Sir Christopher Wren, on the ground of a communication which he made to the Royal Society, in 1662; the journals of which society for October of that year record that "Doctor Wren presented some cuts, done by himself in a new way, whereby he could almost as soon do a subject upon a plate of brass or copper as another could draw it with a crayon upon paper." Now, the engraved works in mezzotinto of Prince Rupert are not numerous, and, we believe, do not exceed twelve in number: his principal work (the "Decollation of John the Baptist," after a design by Spagnoletti) bears date 1658, which is four years earlier than Sir Christopher Wren's communication to the Royal Society. In 1662, the date of Wren's communication, the Royal Society was founded; and in the same year the celebrated John Evelyn published his "Sculpture," in which the first announcement of the new art, in England at least, appears; and he distinctly claims the honour of the invention for Prince Rupert in a chapter "on the new method of engraving, of mezzotinto, invented and communicated by His Highness Prince Rupert, Count Palatine of Rhine," etc. Evelyn embellishes the chapter with a specimen from the prince's own hand, and concludes it with alluding to an account of the process, which he is preparing to be preserved in the archives of the Royal Society. Now, as we have already seen, Prince Rupert's best performance actually bears date four years earlier, so that there is no pretence for giving the invention to Sir Christopher Wren on the ground of anything which he has produced, or any communication which he may have made in 1662. Nor are the claims of Prince Rupert more valid, since he imposed upon John Evelyn, who in turn, however, unconsciously imposed upon the world, by claiming for Prince Rupert the honour of an invention to which the prince well knew all the while that he had no title.

The real inventor of this art was Louis von Siegen, a lieutenant-colonel in the service of the Landgrave of Hesse Cassel, from whom Prince Rupert learnt the secret when in Holland, and brought it with him to England when he came over a second time in the suite of Charles II. Some curious and very rare prints, purchased on the Continent, and now deposited in the British Museum, place the claims of Von Siegen beyond doubt. In this collection is a portrait dated 1643, which is *fifteen years anterior* to the earliest of Prince Rupert's dates: there is another portrait of the same date; and another by Von Siegen bears the most conclusive evidence of its having been produced in the very infancy of the art; besides which is the fact that Von Siegen frequently attached "primus inventor" to his plates. There are also mezzotinto works by Fürstenburg, dated 1656.

It should, however, be added that the works both of Fürstenburg and Prince Rupert are engraved entirely by the newly-discovered process of mezzotinto, and evince a more matured judgment of its powers than those of its inventor, Von Siegen. It is not improbable, notwithstanding what we have said, that Prince Rupert, by himself, or with the assistance of Wallerant Vaillaint, an artist whom he retained in his suite, may have improved the mechanical mode of laying the mezzotinto ground; but this observation does not apply to the principle of the art. We have abridged these details from a statement which first appeared in the "Penny Cyclopædia," and is considered to set this controverted matter completely at rest, and give the honour of the invention to its real author, the rarity of whose productions hitherto favours unwarrantable pretenders to the merit.

After the Restoration, Rupert was received with honour by the king; and Mr. Warburton tells us that the Prince established a seclusion for himself in the high tower in Windsor Castle, the king having appointed him Governor of the castle, and his residence being the Keep, or Round Tower, which the prince soon furnished after his own peculiar taste. In one set of apartments, forges, laboratory instruments, retorts, and crucibles, with all sorts of metals, fluids, and crude ores, lay strewed around in the luxurious confusion of a bachelor's domain; in other rooms, armour and arms of all sorts, from that which had blunted the Damascus blade of the Holy War to those which had lately clashed at Marston Moor and Naseby. In another room was a library stored with strange books, a list of which may be seen in the Harleian Miscellany.

The prince was an operative inventor: he toiled at his own forge, and was a scientific workman, and forged "the thunderbolts of war his hands so well could throw." That he was of a decidedly inventive and ingenious turn of mind, his experiments most abundantly testify. We find recorded in the "Transactions of the Royal Society" Rupert's mode of fabricating a gunpowder of tenfold the ordinary strength at that time used. Next Rupert invented a mode of blowing up rocks in mines or under water, "an instrument to cast platforms into perspective," an hydraulic engine, a mode of making hail-shot, and an improvement in the naval quadrant. His mechanical labours include an improved lock for fire-arms, and guns for discharging several bullets very rapidly. He also discovered a method of boring guns, which was afterwards experimented in Romney Marsh by a speculator; but some secret of annealing the metal was not understood, except by Rupert, and the matter died with him. More widely known is his chemical composition called "prince's metal," of which candlesticks and

small kitchen pestles and mortars are made: this is an alloy of copper and zinc; it contains more copper than brass does, and is prepared by adding this metal to the alloy. It approaches nearest to the colour of gold. The finest sort is called "pinchbeck," from its improver, and was used in making watch-cases, etc.; it is also named *tombac* (Spanish), and *petit-or* (French). These curiosities are now thrown into the shade by Abyssinian gold and electro-gilding. To the list of Rupert's inventions must be added a mode of rendering blacklead fusible, and rechanging it into its original state. His mode of tempering Kirby fish-hooks is amongst his lesser improvements. His favourite science appears to have been metallurgic chemistry.

In glass-making Prince Rupert fitted up experimental works which adjoined Chelsea College—another enterprise of the day. The Rupert Works proved a nuisance, for we find by the Council Minutes of the Royal Society that the College and lands might have been well disposed of (before 1682), but for the annoyance of Prince Rupert's glass-house, which adjoined it; and Sir Jonas More wrote to the prince, at the request of the Council, urging him to "consider the Society, on account of the mischief his glass-house was doing to the college." This was about the time that plate-glass was first made at Lambeth, in works supported by the Duke of Buckingham. "Prince Rupert's drops" take their English name from having been first made known in England by Prince Rupert, and not from his having invented them, as commonly supposed. Their origin has been much disputed. Now, a drop of fused glass falling into water might easily have given rise to the invention of these drops; at any rate, this might have been the case in rubbing off what is technically called the *navel*—that piece of glass which remains adhering to the pipe when any article has been blown, and which the workman must rub off. In a German dissertation on glass drops and their properties, published in 1695, the author states that he was informed by glass-blowers worthy of credit that these drops had been made more than seventy years before at the Mecklenburg glass-houses—that is to say, about the year 1625. They were exhibited at Kiel as early as the year 1637, and much astonished persons with their effects. They are stated to have been first made at Amsterdam, and called by the French *larmes Bataviques* (Dutch tears). Anthony le Grand states that they came from Prussia; but as the drops were the result of a common operation in glass-houses, their property may have been commonly known among glass-blowers, but not so early observed by philosophers. They were first brought into England in 1660, by Prince Rupert, and in the "Royal Society's Proceedings" occurs this entry:—"Aug. 14th. Sir Robert Moray brought in glass drops, an account of which was ordered to be registered," the experiments being made by command of His Majesty; and the first volume of the Royal Society's register book contains a very long account of them and their manufacture. Butler, in "Hudibras," says—

> "Honour is like that glassy bubble
> That finds philosophers such trouble;
> Whose least part crack'd, the whole does fly,
> And wits are crack'd to find out why."

The drop was called "a kind of miracle of Nature," and through all the universities of Europe it raised the curiosity and confounded the reason of the greatest part of the philosophers. It is thus described in the "Philosophical Transactions:"—"The bubble is in form somewhat pear-shaped; it is formed by dropping highly-refined green glass, when melted, into cold water. Its end is so hard that it can scarcely be broken on an anvil; but if the smallest particle of its taper end is broken off, the whole flies at once into atoms and disappears. The theory of this phenomenon is that its particles, when in fusion, are in a state of repulsion; but on being dropped into the water, its superficies is annealed, and the particles return into the power of each other's attraction, the inner particles, still in a state of repulsion, being confined within their outward covering." It exhibits in the most perfect manner the effects of expansion and contraction; and each possesses this singular property—that if a small portion of the tail is broken off, the whole bursts into powder with an explosion, and a considerable shock is communicated to the hand that grasps it. We remember Rupert's drops, or "hand-crackers," common at fairs, as well as "candle-bombs" (a little water in glass, hermetically sealed), which are of about the same date as the drops.

APPLIED MECHANICS.—XV.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

FLOUR MILLS (*continued*).

THE adjustment of the pressure of the upper stone upon the lower is of the utmost importance in the process of making flour. The major limit to this pressure is, of course, the entire weight of the upper stone. The adjustment consists in relieving the lower stone of part of this pressure, by transmitting it along the spindle.

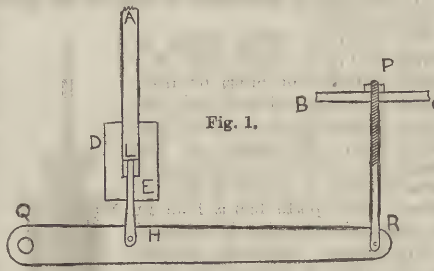


Fig. 1.

To enable this adjustment to be made, the arrangement shown in Fig. 1 is used. Q R is a lever of which the fulcrum is at Q; the power is applied at the point R, by means of the screw R P; this screw passes through a hole in the fixed plate B C, and is raised or lowered by a nut; E D is the lower bearing of the mill spindle, A. The spindle, instead of resting upon the bottom of the bearing, is supported upon a piece, H L. This piece passes through a hole in the bottom of the bearing at E, and is attached to the lever Q R by a pin at H. Thus, when the end R of the lever is raised, the shaft A is also raised. It is easy to see how delicately the adjustment of the pressure can be made with this apparatus. We shall suppose that the arm Q H is one-third of the arm Q R, and that the screw R P contains six threads to the inch. We shall compute the effect upon the distance between the millstones produced by turning the nut P through one-tenth part of a revolution by means of a key or spanner. If the nut were turned round once, the point R would be raised one-sixth of an inch; when the nut is turned through one-tenth of a revolution, R is only raised by $\frac{1}{60}$th part of an inch; the point H only receives a motion which is one-third of the motion of R, and therefore H is only raised $\frac{1}{180}$th of an inch. This is therefore the distance by which the space between the millstones is increased. If the spanner by which P was turned was 8″ long, the extremity of the spanner would describe a circle 25″ long in one revolution. A movement of the end of the spanner through a space of half an inch would raise the point R through $\frac{1}{300}$th part of an inch, and the point H through $\frac{1}{900}$th of an inch. It is thus evident that this mode of supporting the vertical spindle enables the distance between the millstones to be adjusted with the nicest delicacy. This adjustment requires some skill on the part of the miller, which his experience alone can dictate.

Adjustments are also provided for the upper bearing of the vertical spindle. This bearing is fixed in the hole of the lower millstone. The object of the adjustment is to provide that the spindle shall be strictly vertical. X Y Z (Fig. 2) represents the hole in the lower millstone, O is the spindle, and P, Q, R are the three bearings. These are wedge-shaped, so that by movement perpendicular to the plane of the paper, the spindle O can be adjusted vertically above its lowest point.

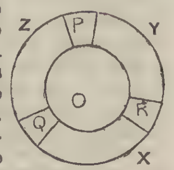


Fig. 2.

MACHINES FOR RAISING WATER.

Machines for raising water are very varied in form, according to the different circumstances for which they are required. Sometimes a small quantity of water has to be raised a considerable height: in this case ordinary force-pumps or lifting-pumps are employed. Sometimes, as in drainage and similar works, a vast quantity has to be raised from a small depth; for such purposes the chain-pump and the centrifugal pump are found to be suitable. Again, in other cases, such as raising water from mines, a large body of water has to be raised from a great depth, and pumping-engines of vast power are employed.

We may roughly divide the machines used for these different purposes into three different classes:—

1. Machines which depend upon atmospheric pressure.
2. Machines which depend upon the inertia of water.
3. Machines which simply lift the water.

To the first of these classes belong the well-known forms of the lifting-pump and force-pump. The second class includes the different kinds of centrifugal pumps and the hydraulic ram. The third class contains the Archimedian screw, the chain-pump, and very many other machines.

We shall give a description of some of the machines in each of these classes.

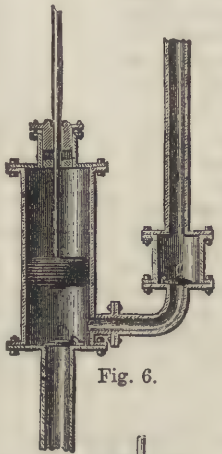


Fig. 6.

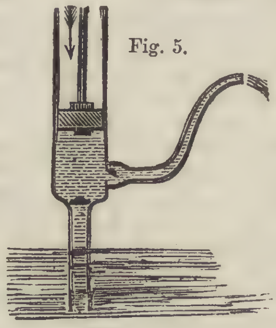


Fig. 5.

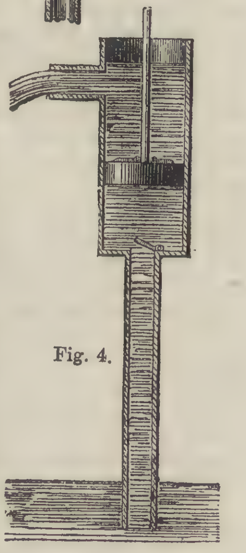


Fig. 4.

Fig. 3.

The common lifting pump is shown in Fig. 3. It consists of a hollow cylinder of brass or iron, cast with a flange at each end, and turned internally so as to be perfectly true. By means of the flanges the bottom, consisting of a circular plate, is bolted to the cylinder. This plate has a hole in its centre, and the pipe is attached to the bottom. Packing, consisting of a ring of leather or some similar material, should be placed in the joints before the bolts are tightened, in order to ensure that the joints shall be water-tight. At the bottom is a valve which opens inwards; when water rushes up the pipe it forces open the valve, and enters the cylinder; when the piston is depressed the valve closes, and will not allow the water to return.

The piston is a circular disk of metal, containing a groove in the circumference, in which the packing is inserted. The packing often consists merely of greased tow, which is sufficiently elastic to make the piston move water-tight in the cylinder. In the centre of the piston are a pair of valves, shown open in the figure. These valves allow of the passage of water from below upwards, but do not allow water to pass from above downwards.

The top of the cylinder is closed by a plate which is bolted to the flanges. The piston passes through the top of the cylinder by means of what is called a *stuffing-box*. It is easy to see that special arrangements must be made for preventing leakage where the piston-rod passes out from the cylinder. If the piston merely passed through a hole in the top of the cylinder, leakage could not be prevented. Even if the piston-rod at first fitted the hole so perfectly that it passed water-tight through it, and at the same time could move freely, this could not last; wear would soon make the piston-rod smaller and the hole larger, and leakage would result. To obviate this difficulty the very ingenious contrivance known as the stuffing-box is used. The piston passes quite freely through the hole in the cover, and then enters the stuffing-box, the object of which is to keep the packing in close contact with the rod. The stuffing-box consists of a hollow cylinder, shown in section. The cylinder is about double the diameter of the piston-rod, and in the space between the cylinder and the piston-rod the packing is placed. The packing may be made of tow and oil. The packing is forced against the piston-rod by a piece which fits freely into the cylinder. This piece is forced downwards by tightening nuts. Thus, when the piston wears a little free, leakage can easily be prevented by forcing down the piece, which will press the packing against the piston. The great power of the screw enables the packing to be pressed as closely into contact with the piston as can be desired. A pipe furnished with a stop-cock, and shown in the figure, is attached to the upper part of the cylinder.

We shall next explain the principle upon which the pump is enabled to raise water. The pipe descends into the well or other reservoir from which water is to be lifted. The piston is placed at the bottom of the cylinder and raised. The air which is in the pipe raises the valve and flows into the cylinder. When the piston reaches the top of the cylinder it is depressed, the valve at the bottom closes, and the valves in the piston open, as shown in the figure, and the air passes from below up to the part of the cylinder which is above the piston. When the piston reaches the bottom of the cylinder the process re-commences. Thus the air is gradually withdrawn from the pipe, and water rushes in to supply its place. The distance from the top of the pump to the surface of the reservoir should not exceed about 28 feet. The water will then gradually fill the tube, and on the ascent of the piston will pass into the cylinder. When next the piston descends this water will pass above the piston by the valve. At the next elevation of the piston the water above will be driven out along the delivery-pipe. The water thus raised may be taken either directly from the pipe, as in the common pump, or, as in what is called the lifting-pump, this pipe may be carried up to the elevation the water is desired to attain. A different form of pump upon the same principles is shown in Fig. 4.

The force-pump, shown in Fig. 5, differs in several features from the lifting-pump. In the former machine the piston is solid, and the valve regulating the escape of the water from the cylinder is placed in the side of the cylinder. The piston is shown in the figure in the act of descending. The cylinder has been filled with water raised through the valve. On the descent of the piston the valve closes, while another valve opens, and the water is forced outwards along the pipe. In a pump of this kind the stuffing-box is unnecessary, as the water does not pass above the piston. In raising water from a great depth, such as the bottom of a coal-mine, the force-pump must be within 28 feet of the water, while the discharging tube is carried up the shaft to the surface above the mine. As the engine which works the pump is at the surface, very long pump-rods are sometimes required. A different form of force-pump is shown in Fig. 6.

MINING AND QUARRYING.—VI.

BY GEORGE GLADSTONE, F.C.S.

COAL.

COKE—ADVANTAGES OF COKING—DIFFERENT QUALITIES OF COKE—VARIOUS PROCESSES FOR COKING—WASTE GASES—PATENT FUEL.

For many purposes it has been found desirable to convert coal into coke prior to using it. When an intense and long-continued heat is wanted, and where the absence of smoke is specially desired, coke may be used to advantage. It is therefore largely employed in factories in towns, and even in private buildings where there are close stoves; but still more on the railways, and in the smelting of iron. The reasons which encourage its use in the latter process will be more particularly

pointed out when we come to treat of that operation; on the railways it is adopted partly to avoid creating smoke, but also because in a locomotive engine economy of furnace-room is an important consideration.

At first sight it would appear that in making coke the coal is being burnt, but though it is raised to an intense heat, that is not, strictly speaking, the case, for the result in such event would be that only the ash would be left. We have already seen in our third paper that a good coal will leave about 3 per cent. of ash, whereas the yield of coke is from 75 to 80 per cent. of the coal employed. It is the volatile and oily portions only which are consumed, leaving the carbon in a very pure condition. In fact, what is classed as best coke contains (after being thoroughly dried) about 97 per cent. of carbon, 3 per cent. of ash, and a trace of sulphur. The per-centage of carbon is the criterion of the heating power, but in practice the result which these figures would indicate cannot be attained, as coke will absorb a great deal of moisture, and seldom contains less than 5 per cent. of water, for which allowance must therefore be made. The facility with which coke imbibes moisture affords dishonest traders a ready means of increasing their profits, and care should be taken by purchasers not to have to pay for more than a fair per-centage of water.

Coke, though very different in appearance, is very similar in chemical composition to anthracite; and like the latter it does not burn satisfactorily without the aid of a powerful draught of air. It is hardly necessary to describe its external appearance, though some importance is attached to the bright metallic lustre; and to be well made and of good quality it should be uniform in character throughout.

The old method of making coke was to roast it in heaps in the open air; and the plan is still kept up in some places, though it is wasteful and does not produce so good an article. It has the advantage of requiring no outlay for plant. These heaps are sometimes circular in shape, while at others they are made in the form of long ridges, sometimes 200 feet in length.

In making the circular heaps the larger lumps of coal are placed upon the ground, and the smaller pieces form the upper and outer portion, until a depth of about two and a half to three feet, and a diameter of twelve to sixteen feet, is attained; a chimney made of loose bricks forms the centre, draught-holes being left between each brick. A few air-channels are left between the large lumps of coal which form the base of the mound, extending from the centre to the circumference, the rest of the heap being covered closely with coke-dust or other waste stuff to exclude the air. Some burning coal or wood is then put down the chimney, which soon communicates its fire to the mass around it. At first a dense cloud of smoke, caused by the bituminous portion of the coal, issues from the chimney; but by the time the fire has pervaded the whole mass, that disappears, and its place is occupied by a blue lambent flame, indicative of the evolution of the gases; as soon as the latter fades away the top of the chimney and all the sources of air are closed up, and the coke, being made, is left for two or three days to cool down, when it is ready to be drawn. For this purpose care has to be taken that the air is thoroughly excluded, or it will continue to burn; and it is usual to put a thicker coating of dust on the windward side. Formerly no chimney was used in these heaps, but a number of holes were left in the mineral, and fire applied to each, no protecting covering of dust being put on until the fire had spread to all parts of the pile: this was, however, very wasteful, as the surface coals were partially consumed, instead of being coked, before the lower portion was sufficiently heated.

The round heaps are not generally found so advantageous as the ridges, because the mass in the former is so great that the outer portions are often insufficiently coked, in which case the coke will be found to retain a portion of its hydrogen and oxygen.

The ridges or rows are long and narrow, sometimes extending 200 feet in length, and have an air-passage running through their whole length, the row being commenced with large lumps of coal inclined towards one another, so as to leave a triangular space between them. The smaller pieces are heaped up till it is about four feet high, and the whole is closely covered with coal-dust. About the distance of every seven or eight feet there is an upright stake extending from the air-passage; this is drawn out, and fire put down the aperture, which rapidly communicates its heat to the surrounding coal, so that the whole ridge is soon aglow, each one of these natural chimneys being in communication with the longitudinal air-channel. As soon as the coking is complete the supply of air is stopped, and the mass left to cool as before.

In some places large open kilns are used, in which 150 tons of coal can easily be operated upon at once. They are generally about fourteen feet wide, ninety long, and seven and a half high. In the walls of the kilns are openings to admit the air, and the large coal is so arranged that the air-passages shall communicate with these openings. The outside of these being fitted with dampers, the draught can be regulated very conveniently. The surface of the coal inside the kiln is covered with coal-dust as in the open heaps. The mass of coal in these kilns is, however, so large, that there is a risk of burning away the coals in the neighbourhood of the air-passages before the rest of it becomes properly carbonised. It is therefore doubtful whether in the end anything is gained by their adoption.

This leads us to the consideration of the most approved method of coking—viz., in ovens. This plan is now very largely practised. The simplest form of coke-oven is a circular building of fire-brick, with a doorway in the front, covered in with a rather flat vaulted roof, in the top of which is an opening. The oven is filled with coal up to about the springing of the roof; the doorway is then filled in with loose bricks so as to allow the entry of a little air; and as the coking proceeds the door is more effectually closed by plastering it up with clay and sand, beginning at the lowest row of bricks and working upwards, the topmost row being left untouched for some hours longer. When all flame has disappeared, the hole in the roof is also closed with a stone slab, and every crevice stopped up with loam. After remaining shut out from the air for about twelve hours, the charge is ready to be drawn. The door is then broken open, and the coke is drawn out by means of rakes into iron barrows or trucks and carted away. Some water is often sprinkled upon it immediately on its being drawn from the oven, to cool it more rapidly. Nothing is said here about setting fire to the coal; in fact, that is not needed to be done, for the coking operations go on continuously day and night, and the ovens are never allowed to get cool, so that the heat radiated from the walls and roof is sufficient without further assistance to set the charge on fire.

Various improvements upon this rudimentary form of coke-oven have been made, and some that have been proposed really convert them into elaborate structures. Some of the principal modifications, and the reason for them, must however be noticed.

As a matter of economy, it is of importance not to allow any more of the heat to escape than can possibly be avoided. The walls are therefore made very thick, and the roof covered over with sand or some other bad conductor of heat. A coke-oven never stands alone, but a number are built together, so that one shall keep the other warm: they are generally arranged in a double row, back to back. Many of the best ovens have a double roof, and the waste gases from the coal pass through the space between the two roofs on their way to the chimney. One tall chimney serves to carry off the gases from a large number of ovens; and by a little careful management very little smoke need be produced during the operation, as it is only in the earlier stage of the coking process that smoke is produced at all. The waste gases are often made to contribute still more to the maintenance of the heat in the ovens, by the flues being carried through the walls and under the floor of the ovens, so that the gases have to make a considerable circuit before passing away. This arrangement possesses the special advantage of expediting the action in the lower portion of the charge, which in the simple ovens is the last part to get coked, as the heating there commences at the top and gradually works downwards.

In many of the improved ovens the supply of air is not limited to what enters by the upper portion of the door, but is admitted by small air-passages passing through the walls in various parts, but always above the surface of the charge; the supply from these can be regulated with much nicety, and the air is thus distributed equally over all parts of the charge, instead of being all directed upon one point.

The raking out of the coke when made is not only a hot and laborious process, but the time occupied by it allows of the ingress of a great deal of fresh air, which tends materially to cool the oven itself. Both these objections are obviated by the use of what is called the *drag*. It consists of an iron bar which lies along the floor of the oven from the door to the back, with a

long piece of flat iron fixed at right angles. This is put in its place at the back of the oven, before the coal is introduced, and remains there throughout the process: when complete a chain is attached to the fore end of the iron bar, and with the help of a windlass the whole charge is drawn out in one mass. Where the drag is used the lower part of the oven must be rectangular, and the width of the door increased.

Figs. 12, 13, 14, showing the *plan*, *elevation*, and *section* of coke-ovens, will serve to illustrate the foregoing descriptions. They represent a portion of a double row of eighteen ovens, communicating with a chimney stalk 115 feet high. These ovens have iron doors, which are hung with counter-weights, and raised or lowered by a crane. Within is a second door made of fire-bricks. The exterior of the ovens is bound with iron. The floor rests upon a bed of concrete, and the supply of air can be regulated by the damper plates in the channel connecting the oven with the flue. Every alternate oven is charged in succession, so that while the one is having the coke drawn and being re-charged, those on

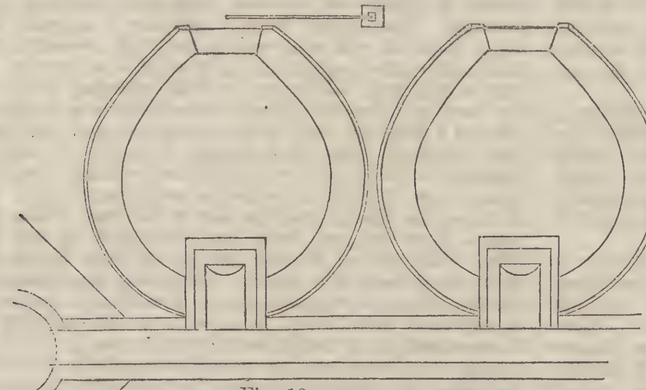


Fig. 12.—PLAN OF OVENS.

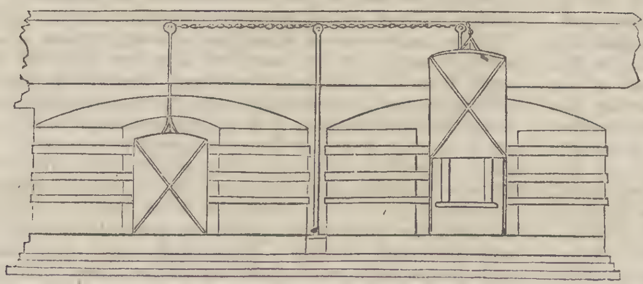


Fig. 13.—ELEVATION OF OVENS.

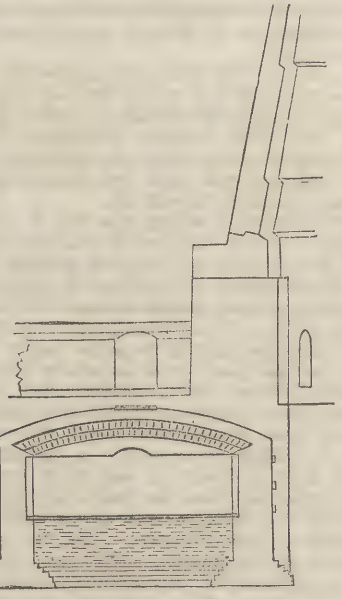


Fig. 14.—SECTION OF OVENS.

either side are at their full heat. Each oven treats three and a half tons of coal at a time.

The amount of heat which is generally wasted is very considerable, but it may be easily turned to profitable account. Thus at the large iron-works of Seraing, in Belgium, the boilers for the steam-engines are erected over the coke-ovens, so that twenty-four ovens supply all the heat required to work two engines, by which a saving of nine to ten tons of coal per day is effected.

The coking process does not altogether drive off the sulphur contained in coal, and to reduce the quantity of this obnoxious ingredient the coal is sometimes washed first, and some add a little common salt in order to convert the sulphur into sulphate of sodium.

It is well known that coke is not the only product of coal which is yielded by the agency of heat; but the others are not regarded by the coke-burner, because a different temperature from that which suits him best is needed for their production. The common illuminating gas is the most familiar of these articles, which is produced by distillation at a high temperature; and though a quantity of coke is left in the retorts of the gas-works, it is of a different character from that described here, and is of very little value as an article of fuel. Gas-making will be treated in a separate series. The tar and other oily hydro-carbons are evolved, on the other hand, at a temperature somewhat below a dull red heat: some of the products of these are described in "Chemistry applied to the Arts," papers II. and IX. All these substances, both gaseous and liquid, are sacrificed to the carbon in the coking process, while in the other the quantity of carbon desired is only so much as will enter into chemical combination with the hydrogen.

Patent Fuel.—Small coal and coke-dust have lately been economised by converting them into patent fuel. Several patents have been taken out for this purpose, and there are some very large establishments in England and Wales for the working of them. The general principle involved in them is to work up the slack and dust with just sufficient coal-pitch or tar to make it cohere, and then compress it into solid blocks. For this purpose the materials have to be somewhat warmed, so that the pitch becomes softened, and the mixture reduced to a pasty mass. In order to make a hard fuel which shall stand a hot climate without fear of spontaneous ignition, the heat is raised to 400° or even 600° Fahrenheit, by which means the more volatile ingredients are all driven off. Such fuels are much used on board steam-vessels; and for navigation purposes the small coal used in their manufacture is generally that derived from the best steam coals: being made into blocks considerably larger than ordinary bricks, and all of uniform size, they are very easily handled, are very economical in stowage, and cause less dust, which are all considerations of some importance on shipboard. The analysis of a good patent fuel will give about 86 to 90 per cent. of carbon, and the specific gravity will vary from 1·13 to 1·18. The loss in actual density of the fuel as compared with large coal is balanced by the closeness with which the blocks can be stowed on shipboard.

A fuel may even be prepared from some kinds of small coal without the use of pitch or any other ingredient of that kind. By selecting that derived from a good caking coal, and heating it up just to the caking point, it will cohere sufficiently to form a firm block after it has passed under heavy pressure.

The unavoidable production of coal-dust is so great, that the accumulation of it in large workings leads to much inconvenience. In the face, too, of the rapid consumption of large coal, these appliances for turning to account the heaps of coal-dust which were formerly considered as dead loss, cannot but be regarded as of the highest importance.

PRINCIPLES OF DESIGN.—XVII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS.

It is not my intention in this chapter to consider in detail the various kinds of carpet which are common in our market, nor even to review the history of their manufacture, interesting as it would be to do so; for we must confine ourselves more particularly to an examination of the art-qualities which they present, and to the particular form of pattern which may be applied to them with advantage.

Although we cannot here enter into a consideration of the manufacture of carpets, I cannot too strongly recommend all who intend preparing designs for them to consider minutely the powers of the carpet loom; for the nature of the effect produced will depend to a large extent upon the knowledge which the designer possesses of the capabilities of the manufacture for which he designs patterns. In the case of any manufacture it is highly desirable, if not absolutely essential, that the designer of the patterns to be wrought should be acquainted with the process by which his design is to be converted into the particular material for which the pattern has been prepared; for this knowledge, even when not absolutely essential, gives an amount of freedom and power which nothing else can supply.

The carpets most extensively in use are "Brussels;" but there are many other kinds both of better and inferior qualities. "Kidderminster carpet" (a carpet not now made by even one Kidderminster manufacturer) is a common fabric suited to the bedrooms of middle-class houses; but the art-capabilities of this material are very small, as it can only have two colours in any line running through its length. This carpet consists of two thicknesses, which are imperfectly united, and is not durable. "Brussels carpeting," now made chiefly in Great Britain, is a good carpet for general purposes. Its surface consists of loops, and it may have five, or, if made of extra quality, six colours in any line running throughout its length. If with five colours in the same line the carpet will, in a sense, consist of five thicknesses of worsted; yet these are united into one fabric. In some cases a "Brussels carpet" is woven of very close texture where the loops are all cut through; thus we have formed a "velvet pile" or Wilton carpet"—a fabric which is very rich looking, and durable.

Those called real "Axminster" carpets are, perhaps, the best made. They are formed by the knotting together of threads by hand, consequently any number of colours may be used in their formation; but such are necessarily most costly. A "patent Axminster" carpet is made by a double process of hand-weaving, by which fine results are achieved, and any number of colours used. In the first weaving a rough "cloth" is formed, which is cut into strips called "chenille threads," and these are woven into the carpet. This process is most ingenious, and the carpets produced by it are very good; but they are costly.

Messrs. Crossley and Sons, of Halifax, some few years since patented a most ingenious process of manufacturing what are known as "tapestry" carpets—a process resembling in its nature that of the patent Axminster manufacture, but differing in this particular, that the "warp" threads, answering to the chenille threads of the patent Axminster, are coloured by printing, and thus the first process of weaving is dispensed with. These carpets are, like Brussels, made with a looped surface, and also with a pile. They cannot be said to compare in any way with the patent Axminster carpets, which are of a pretentious and costly character, nor even with a good "Brussels;" but they are low in price, and meet a want, as is proved by their enormous sale.

Besides these varieties of carpet there are a number of kinds of foreign production, most of which are hand-made, and are very beautiful. By far the greater number of these have a "pile," although this is sometimes rough and uneven, yet rarely, if ever, inartistic; but a few are without pile; still these are not without that indescribable something which renders them estimable in the eye of an artist.

Having hastily noticed the chief kinds of carpet in use in this country, and we might say in almost all countries, we come to the question—what form of pattern, or what character of ornament, should form the "enrichment" of such a fabric?

When speaking in a previous article (see page 119) of wall decorations, we noticed that a wall-paper pattern, or, indeed, a wall pattern of any kind, might desirably have an upward direction and a bilateral symmetry. This can never be the case, however, with a carpet pattern, which must be equally extended all over the surface, or have a simple radiating symmetry, as Fig. 54; and this rule will apply whether the pattern be simple or complicated. It is not wrong, as we have said before, to have a radiating pattern on a wall, but it is wrong to have such a pattern on a floor.

Fig. 54.

The reason of this is obvious. If such an object as we have indicated is placed on a wall, from whatever point the occupants of the room may view it, it is yet right way upwards to them; but if such an object were placed on a floor it would be wrong way upwards, or sideways, or oblique to most of those who viewed it; and to employ a pattern of this character in such a position is highly absurd, when a pattern can as readily be formed of such a character as will avoid this unpleasantness. What would we think were we asked to view a picture, or even to visit an apartment containing such, were this work of art presented to our view in an inverted manner? We should feel astonished at the absurdity; yet this would be no worse than expecting us to view a carpet while the pattern is to us in an inverted position.

And the principle which we have just set forth is one taught by a consideration of plants. If we wander over the moor, where we tread on Nature's carpet, we find that all the little plants which nestle in the short mossy grass are "radiating ornaments"—that is, they are pretty objects which consist of parts spreading regularly from a centre.

I cannot too strongly advise the young ornamentist to study the principles on which Nature works. Knowledge of the laws on which plants grow is very desirable; yet it is not our place to *imitate* even the most beautiful of plant-forms—this being the work of the pictorial artists. Yet it is ours to study Nature's laws, and to observe all her beauty, even to her most subtle effects, and then we may safely pillage from her all that we can *consistently* adapt to our own purposes. But in order that we produce ornament, we must infuse mind or soul into whatever we borrow from her.

With the view of more fully impressing the manner in which Nature teaches us principles which we may apply in art, and of aiding the student in his inquiries, we will give one or two

illustrations. Thus Fig. 55 is a drawing of a spray of the guelder rose (*Viburnum opulus*) when seen from the side, or, as I might express it, when viewed as a wall decoration; and Fig. 56 is the same spray as seen from above, or, to use the same manner of expression, when seen as a floor pattern. Further, Fig. 57 represents a young plant of a species of speedwell (*Veronica*) as a wall ornament, and Fig. 58 the same plant when seen as a floor ornament; and Figs. 59, 60 represent a portion of the goosegrass (*Galium Aparine*) as seen in the same two views.

From these illustrations we see that plants furnish us with types of two essentially different ornaments which are adapted to the decoration of the two positions of wall and floor, and may be introduced with truthful expression and effect into wall-paper or carpet.

Even when the leaves appear somewhat dispersed upon the stem, a principle of order can yet be distinctly traced in the manner of their arrangement, as is diagramatically expressed in Fig. 59; and here, also, the top view gives us a regular radiating ornament.

The same law prevails in the flower that we have traced as existing in the arrangement of leaves upon the stem: thus Fig. 61, which represents the London pride (*Saxifraga umbrosa*), affords an example of a regular radiating flower, which we find so placed, in different examples, as to appear as a floor or wall ornament; and Figs. 62, 63, the former being the flower of the speedwell (*Veronica*), and the latter that of the common pansy (*Viola tricolor*), furnish us with illustrations of bilateral flowers intended only as wall ornaments. In order to secure our seeing the pansy only laterally, it is furnished with a bent stalk; hence it never rests horizontally upon the summit of its stem, but always hangs so that it is perfectly seen only from the side.

There are cases, however, in which bilateral flowers are placed horizontally; but it is very interesting to notice that when this occurs the disposition or arrangement of the flowers is such as to restore the radiating symmetry. Thus, if we take the candytuft (*Iberis*) or the common hemlock (*Conium*), we find that while each flower is bilateral in character, the flowers are yet arranged around a centre in such a manner that the smaller portion of each flower points to the centre of the flower-head, while the larger parts point outwards from the centre of the group. These, then, are the teachings of plants, to which we are called upon to hearken.

The above illustrations are not only useful examples of the adaptation of plant-forms to ornamentation, but form excellent guides to the art-student for the conventional treatment of leaves and sprays, buds and blossoms. They will also serve to indicate the kind of plant-forms that should be chosen for decorative purposes. Students of this branch of art would find it a useful practice to make a collection of any flowers and plants or parts of plants that appear to offer features similar to those of which we have been writing, and test their capabilities for decorative purposes, by endeavouring to arrange them for ornamentation of wall and floor, as we have treated the plant-forms named in this paper.

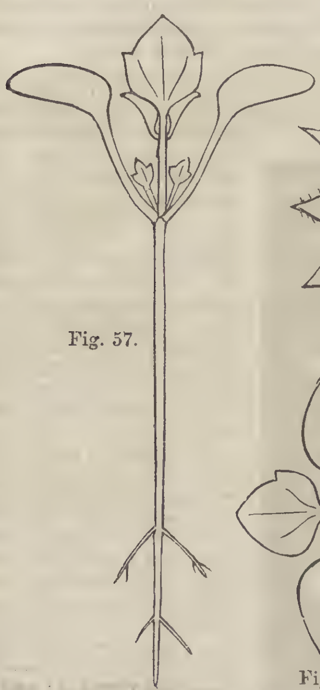


Fig. 57.

Fig. 60.

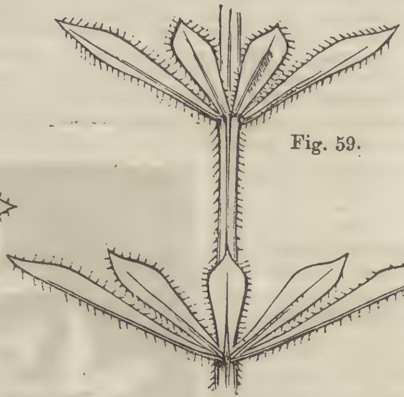


Fig. 59.

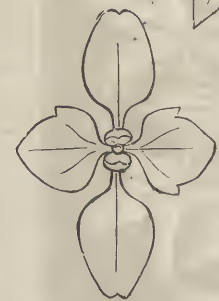


Fig. 58.

Fig. 62.

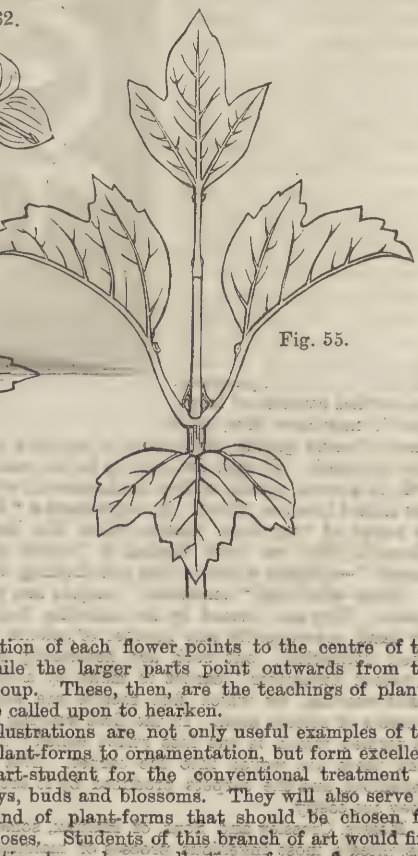


Fig. 55.

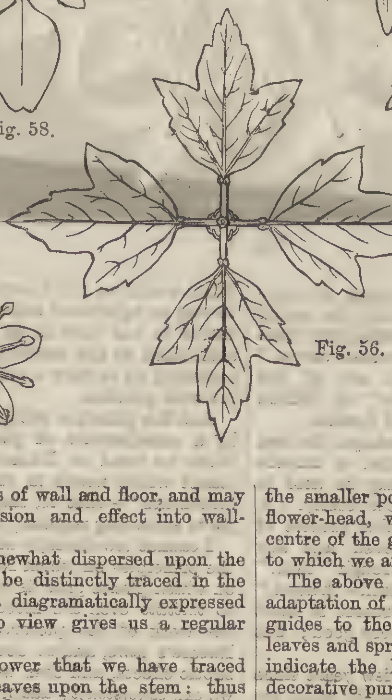


Fig. 56.

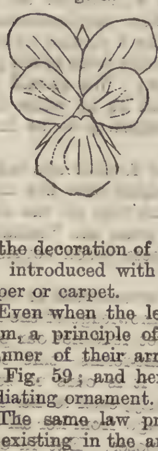


Fig. 63.

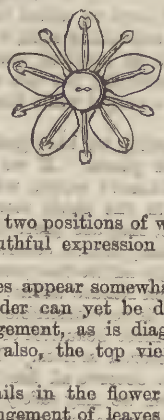


Fig. 61.

THE ELECTRIC TELEGRAPH.—XI.

By J. M. Wigner, B.A.

BONELLI'S PRINTING TELEGRAPH — ALPHABETICAL INSTRUMENTS—BREGUET'S—WHEATSTONE'S UNIVERSAL.

In our last lesson we described several forms of chemical telegraph; there is, however, one more to which we must refer before we leave this class of instruments. This is known as Bonelli's Printing Telegraph, and by means of it the message is printed in ordinary Roman characters, and that too at an almost incredible speed. It is said by those who have used the instrument that, when the message is printed in fugitive ink, a teeth of a comb, and are connected with the five line-wires. At the receiving station are five somewhat similar pointers, connected with the corresponding wires, and the chemically prepared slip is made to pass along under these, so that, if constant currents were passing, five parallel lines almost touching one another would be traced on the slip. The current, however, only passes when the raised part of a letter comes against a contact-spring or pointer, and thus the marks traced correspond to the raised parts of the type, and we have an almost exact copy of the type printed at the receiving station.

An enlarged copy of a message as received by this instrument is given in Fig. 48, and will explain the whole action.

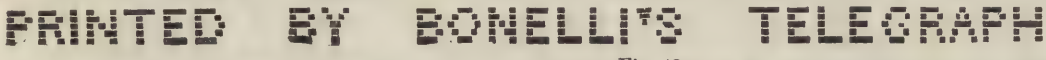
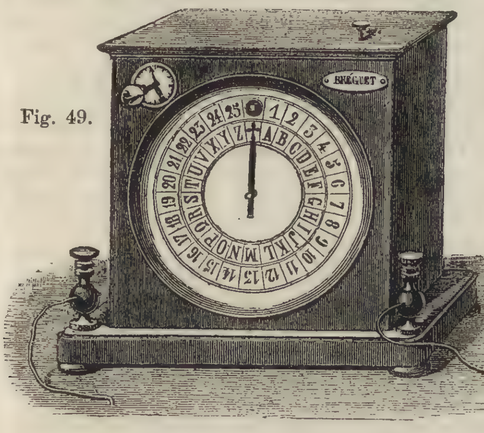


Fig. 48.

Fig. 49.



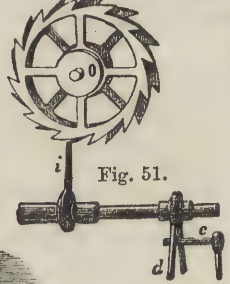


Fig. 51.

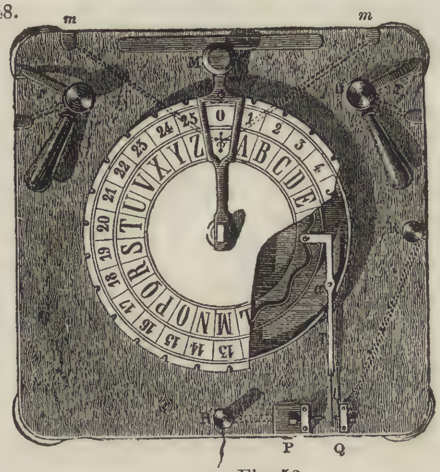
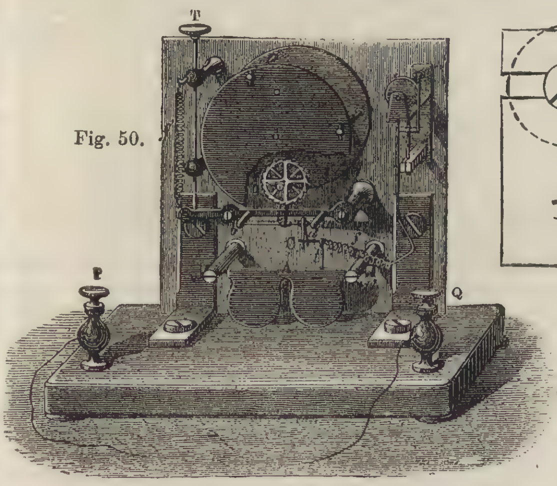


Fig. 52.

Fig. 50.



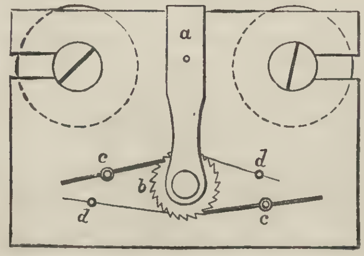


Fig. 54.

Fig. 53.

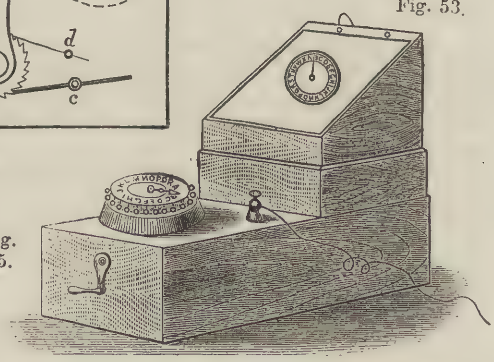


Fig. 55.

speed of more than a thousand words a minute may be attained, and in permanent characters from 200 to 300 words may be sent in the same time. There is, however, one very great drawback to the use of this instrument, and that is the fact that it requires five wires, and thus it can only be made to pay on lines where a great many messages are continually passing.

The instrument consists virtually of five pointers placed side by side, each of which acts in the same way as the one pointer or pen in Bain's instrument. The message is first set up in metal type, block letters and capitals being employed. Ordinary printing type will not answer, however, since it is left-handed, and, besides, is so soft that the metal would soon wear away. Brass letters are therefore used, and when set up they are placed on a metal tray connected with the earth-plate, and made to pass under the pointers.

Of these there are five, which are placed side by side like the

This instrument is a very ingenious and reliable one, but, for the reason referred to, it has not come into general use. The whole class of chemical telegraphs are in fact chiefly valuable as showing what may be accomplished by means of electricity; none of them, we believe, being practically employed in this country to any great extent at the present time.

We must now pass on from these instruments to our last class—namely, the alphabetical or dial instruments. In most of the telegraphs already described the message is sent in some cipher or code, and the instrument can only be used by the initiated, some considerable amount of practice being required to attain even moderate facility in its use. For many reasons, however, it is a great advantage to have an instrument so simple that any one with a little care and understanding can work it. This is especially the case where, as is frequently done in the present day, a wire is fitted between two or more

different offices of any house of business, or between an office and a factory.

Very many instruments have accordingly been invented in which a pointer is made to travel round a dial on which the letters of the alphabet are engraved, and to stop at any required one; so that the message to be sent may be spelled out in this way letter by letter. These are sometimes distinguished as step-by-step motion telegraphs. We cannot even mention all the different instruments of this kind that have been introduced, but will describe one or two of those which best illustrate their construction, and from these the action of most others may, with a little thought, be understood.

Breguet's Alphabetical Telegraph will convey a good general idea of this class of instruments. In it, as in several we have already described, the receiving and transmitting portions are entirely distinct. Fig. 49 represents the former of these, and Fig. 50 a back view of the same instrument, the case, and also the magnet, which occupies a position facing the dotted circles on A, being removed for the sake of clearness.

Round the face are placed the 25 letters of the French alphabet and the sign +, which is given at the end of each word, while in an outer circle the numerals from 1 to 25 are arranged.

In an English instrument there are usually 30 divisions on the dial-plate, for the 26 letters, the comma, semicolon, full stop, and +. Inside the case is some clockwork, which is wound up by the axle seen on the face between 25 and 1. This clockwork causes the hand to travel round the face at a considerable speed, but its motion is stopped or regulated by the escapement seen at Q, an enlarged view of which is given in Fig. 51.

It consists of two ordinary scape-wheels mounted on the same axle in such a way that the teeth of one are alternate with those of the other. A small pallet, *i*, is fixed under this, and is so arranged that as it vibrates backwards and forwards, it alternately catches the teeth of each wheel; in this way, each movement of the pallet allows the wheel to revolve one twenty-sixth part of a revolution, and as the hand on the dial-plate is fixed to the axis of this wheel, it allows the hand to move forward one letter.

We have now to see the way in which this movement of the pallet is controlled by means of the electric current which arrives along the line-wire, and passes round the coils of the magnet. The keeper or armature, A (Fig. 50), is suspended so as to swing freely on pivots fixed in the supports V V′, and carries with it a small arm, *l*, having a pin, *c*, inserted at one side of it. A spiral spring, *f*, passes from the top of *l* to a wire fixed to the stand, and thus keeps the armature away from the magnet when no current is passing.

The armature therefore swings to and fro as the circuit is made and broken at the sending station, and this alternate motion is communicated through *l* and *c* to the fork *d* (Fig. 51), and thus to the pallet *i*, which at each movement allows the hand to move forward one letter. If then it be set to +, and a current be transmitted along the line-wire, the hand will move forward to A, and there remain as long as the current passes. As soon as it ceases, the spiral spring will draw away the armature from the magnet, and the hand will move to B. Thirteen currents are thus required to allow the hand to complete its revolution round the dial, and the transmitting apparatus has to be so arranged that we may easily cause the required number of currents to be sent so as to stop the hand at any given letter.

Sometimes, however, the hand will get wrong, owing to the receiving clerk interrupting the message, or from some other cause. A small rod with a milled head, T, fixed to it, is therefore provided. By pressing on this the pallet is entirely removed from the scape-wheel, which, being thus set free, rotates until the hand points to +, where another stud stops it.

The transmitting apparatus, which is far simpler in its construction, is shown in Fig. 52. It consists of a large dial-plate with the letters arranged round it just as in the receiving instrument, and a small notch is cut in the rim opposite each letter. A handle, M, is fixed to a pivot in the centre, and has an opening or slot cut in it. This is moved round in one direction following the order of the letters, till the one we wish to send is seen through the slot. A small peg in its under side catches in the notch against the letter, and ensures it stopping at the right point. If by any chance the handle is moved beyond the letter, we must not move it back, but must carry it quite round till it again comes to the required letter.

A portion of the dial is removed in the figure, and shows a wheel underneath, which turns with the handle. In this wheel a sinuous groove is cut, having thirteen elevations and as many depressions. A small roller fixed to a pin on one end of the bent lever T works in this groove, and thus for every revolution made by the hand M, this lever is moved from side to side thirteen times.

At the lower end of T is a spring faced on each side with platinum; as the lever vibrates this comes alternately into contact with the screws P and Q, the former of which is connected with the line-wire. The battery-wire is connected to *m*, and thence the current passes to the grooved wheel, and along the lever T.

We can now understand the action of the apparatus. Let us move the handle to the letter A, the lever T will at once be moved till its lower end comes in contact with P. The current will then pass from the battery, through the wheel, along T, and by way of P to the line-wire. It will then cause the magnet at the receiving station to attract its armature, and thus let the hand there move to A likewise. If now we move the handle to B, the lever will be inclined to the other side, and the current will thus be interrupted. The magnet at the other end then ceases to act, and the armature being released, lets the hand move forward another letter to B. In this way, we have only to move the handle to any letter we like, and the same letter will be indicated at the other end. The message is thus spelled out letter by letter, a short pause being made between each.

The handles seen at the upper sides of the receiving instrument serve to make the current pass to the alarum, or the receiver, at pleasure.

At the end of each message the handle is turned twice round to show that it is complete, and the receiver, if he has understood, acknowledges by a similar sign.

This instrument is an electro-magnetic one, and requires a battery; there are, however, several somewhat similar ones, which are purely magnetic, and in which, therefore, all the trouble of a battery is avoided. The one of these most generally used was invented by Wheatstone, and is now employed on nearly all the private lines in London.

In this the receiver is usually made to stand on the upper part of the transmitting apparatus, as seen in Fig. 53. The latter consists of an oblong rectangular box, on the top of which near the front is a raised dial-plate with the letters of the alphabet and the signs , ; . and + engraved round it. In the centre is a hand which is moved by a handle in front, and points successively to these various signs.

Outside each letter is a small stud or button which can be pressed down by the finger; these are so arranged that when one has been depressed, it remains so until another is pressed down, but the act of doing this raises the former, so that only one stud can be down at the same time. In the front is seen a small handle which is continuously rotated by one hand, the other being employed in pressing down the required studs. When that opposite any letter is touched, the pointer is free to move round to that letter, and there it remains until another stud is pressed down, so that in sending the message we have merely to press down in succession the studs corresponding to the letters, and thus spell it out.

Inside the instrument is a second hand fixed to the same axis as the pointer and turning with it. This is so placed that when any stud is depressed it catches against it and stops its further progress. The movement of this pointer is thus entirely mechanical, but an arrangement is also made by which at the same time a short circuit is made, so that no more currents pass along the line till the hand is again free.

One great advantage of this instrument is that the armature is kept constantly rotating by the handle. In this way its movement is much more regular, and the danger of the needle "skipping" is greatly reduced. The internal mechanism is simple; several thin horse-shoe magnets are screwed together to form a compound one of considerable power, and two bobbins wound with fine wire are placed side by side on each pole. The cores of these four are arranged in a circle, and the keeper rotates in front of them. The alternate bobbins are wound in reverse directions.

When the armature, which turns on a pivot in the centre of the four bobbins, is in front of the first and third, a momentary current is produced, which travels along the line-wire; as the armature passes to the alternate pair, a current in the reverse direction is generated, and thus by the continuous motion of the armature alternate currents are sent.

The armature and pointer are both set in motion by the handle seen in front of the instrument, and are so adjusted that for each current sent the pointer advances one letter. As soon as the pointer is arrested by any stud, the currents are, as we have seen, intercepted.

We must now turn our attention to the receiving apparatus, in which there is a small dial and hand similar to the large one. The currents pass round two slender bobbins, placed side by side, the ends of which are represented by the dotted circles in Fig. 54. Between these there is a pair of magnetised needles reversed and mounted as seen in Fig. 55, and the alternate currents cause this compound to oscillate, the opposite poles being alternately attracted and repelled. To the upper end of their axis is fixed the arm *a* (Fig. 54), which carries the ratchet-wheel, *b*. As this arm oscillates, the slender screws, *c c*, alternately catch in the teeth of *b*, and thus at each movement advance it half a tooth, or one letter on the dial, for the pointer is fixed to the axis of this wheel. The hair-springs, *d d*, prevent the wheel moving unevenly.

A small handle is always provided under the upper dial by means of which the needle may, when required, be brought to +. If at any time the receiving clerk fails to understand a word, he at once interrupts by working his own instrument. This throws both needles out; both operators then cease working, taking care to leave the large pointers at +; they then bring their receiving pointers to the same sign, and are ready to resume. If the needles do not all agree at starting, it is clearly impossible to make the message understood.

An alarum is always used with this instrument, and by moving to the left the lever seen behind the receiver, this is brought into circuit, and the receiving instrument shut out.

We have ourselves used an instrument of this kind for a considerable time, and found it very simple, and with ordinary care not liable to get out of order.

TECHNICAL DRAWING.—XXXVII.

DRAWING FOR STONEMASONS.

A CONCISE HISTORY OF MASONRY.

Although the purpose of these lessons is to teach drawing of precisely the kind necessary for stonemasons, still it is hoped that a brief sketch of the history of masonry will not be unacceptable.

The art of building in stone is one of the greatest antiquity, dating possibly from the first human family. We find that when Cain was driven by his sin to become a wanderer from his native place, and when a son had been vouchsafed to him, he "builded a city," and called it, after the name of his son, Enoch (Hebrew, *dedication*). We have, of course, no data to give us the slightest idea of the extent of the buildings which constituted this primitive city, but, from the word used in the original, it is most probable that permanent structures of the form of caves were erected.

There can be no doubt that from the moment when our first parents were driven from Eden to till the ground and to labour, they must have felt the necessity for some place where their children might be nurtured and protected from the rays of the sun.

The umbrageous trees and the skins of animals might at first have proved sufficient; but a better shelter would at once have been suggested by holes in rocks or natural caves. These, however, could not be found everywhere. What is more natural than that wooden huts should be erected, and that these, being perishable, should, when circumstances allowed, be superseded by stone buildings? And thus the trunks of trees, and beams laid across them, probably gave the original ideas for the columns and architraves of the subsequent erections in a more permanent material.

Amongst the earliest nations of the world heaps of stones were regarded as a memorial of some event, or as emblems of the permanency of the agreement entered into. Thus we find Jacob took a stone and set it up for a pillar, and said to the people, "Gather stones," and they took stones and made a heap, and both parties called it by a name which, in the language of each, signifies "the heap of witness." Several such instances occur in sacred history.

Amongst rude and barbarous people there seems in all ages to have existed this desire to erect huge masses of stones, either to commemorate some triumph, or for the exercise of their religious rites; and the early history of almost every nation contains records of some such structures.

Of the early history of stone-work, Mr. Ashpitel says: "The necessity for defence against predatory tribes seems to have given the next impulse to building in stone; and to this we probably owe those extraordinary walls called Cyclopean or Pelasgic. These consist of huge polygonal blocks of stone carefully cut, so as to fit exactly to each other without mortar, forming walls which must have been impregnable at that time."

An idea of their size may be gathered from the fact that in the Etruscan walls at Rusellæ, Mr. Dennis measured a stone 12 feet 8 inches long by 2 feet 10 inches high. Most of the stones forming these walls would weigh from six to eight tons. It seems very difficult, considering the deficiency of machinery at the period, to imagine how they were hoisted. Pausanias,* describing those of Argolis, says: "The walls, the only remains of the city left, are the work of the Cyclops, and are made of rough blocks of such a size that a yoke of mules would be unable to move the smallest."

The masonry practised in Assyria possesses this peculiarity—that, excepting at the angles, it formed only a facing to the immensely thick walls, which were filled up in a manner to be subsequently described; and it is especially interesting to us from its great antiquity.

Mr. Layard, to whom the world owes so much for his discoveries in Assyria, tells us that 600 years before the Christian era, Nineveh ceased to be a city, and Assyria an empire. Cyaxares, at the head of a vast army of Babylonians and Persians, captured Nineveh after a short siege, destroyed its walls and palaces, and left it what it has remained to this day—a heap of ruins. The Assyrians, after the destruction of their capital, became subjects of the King of Babylon, and appear no more in history as an independent people.

The main cause of the utter disappearance of Nineveh is to be found in the circumstance that the buildings were not erected of stone, but merely faced with it; and not always this, for their palaces, public buildings, and private dwellings were erected of bricks made of clay, mixed with chopped straw—in most cases dried in the sun; but, evidently, stone was not a general building material, for in erecting the Tower of Babel we find the people saying, "Come, let us make bricks, and burn them thoroughly" (thus implying that *thorough* burning was not usual); "and they had brick for stone, and slime (*bitumen*) had they for mortar."

Marble, alabaster, and kiln-burnt bricks, sometimes painted and sometimes glazed, were used by the Assyrians in their principal buildings, but only in the way of ornament. The whole of the upper portions of the buildings were of wood, and hence, when the buildings were once deserted, the upper portions decayed and fell in. The sun-burnt bricks, which formed as it were the core of the walls, became earth again. Their support thus being withdrawn from the slabs, the ruins assumed the appearance of mere natural heaps or mounds rising in the plain, upon which grass grew and corn might be sown. And such have been the ruins of Nineveh for more than 2,000 years.

The Assyrian palaces and public buildings were erected in terraces thirty or forty feet above the level of the surrounding country. These platforms appear to have been supported by solid masonry of limestone. The line of elevation was broken by flights of steps or inclined ways, by which the terrace was reached. "The object," says Mr. Layard, "of raising these great platforms, which must have demanded scarcely less labour and expense than the superstructure they were destined to sustain, was twofold—to give to the royal or sacred edifices additional

* Pausanias, a Greek geographer, who lived in the second century. He wrote "Accurata Græciæ Descriptio," in which he gives a very minute account of the topography of Greece, and of its buildings and ruins as seen by himself.

dignity and grandeur, and to secure, in a climate remarkable for its intense heat during the summer months, as much coolness as possible. In some cases, too, especially in the lowlands of Babylonia, they may have served both as a means of defence and to protect the buildings against the effects of the inundations to which that country is subject." Several of the alabaster sculptured slabs, and of the human-headed bulls brought from Nineveh, may now be seen in the British Museum, and copies of them form parts of the admirable reproductions in the Nineveh Court of the Crystal Palace at Sydenham.

The Egyptians seem not only to have used gigantic masonry, but also to have had the power of working, carving, and polishing granite to a marvellous degree. A strange fact connected with their masonry seems to be, that the whole work was executed with copper, or rather bronze tools, which seem to have answered their purpose better than even our best or hardest steel. Such seems to have been the facility with which they worked this untractable material that they were not content to cut and polish huge slabs and masses of granite, but they covered them all over with the most delicate and sharp-cut hieroglyphical inscriptions.

Mr. Owen Jones, to whom we are indebted for the admirable reproductions in the Egyptian Court at the Crystal Palace, says: "Egyptian architecture, or rather Egyptian art—for painting, sculpture, and architecture are so intimately united that they are inseparable—is the parent of every other. Undoubtedly the most ancient, its remains are still the most abundant. The Egyptians built for immortality, and obtained it. Whilst obedient to religious laws which limited the direction of their art, they combined the highest sublimity of conception with the most refined and delicate finish in execution."

Whilst they originated, they excelled at the same time all that followed after; they are inferior only to themselves. In every other nation, art exhibits its progress in the same phases, namely, a rapid ascent from its infancy to the culminating point of perfection, from which there is a slow, lingering decline; but in Egypt, the farther we go back the more perfect is the art. We are not even acquainted with its culminating point, much less with any trace of its infancy. In the most perfect temples which have been discovered there are stones built in the walls, with hieroglyphics on the inner side, of a higher character of art than can be found on existing monuments. These were evidently stones from ruins of more ancient buildings. Two kinds of walling were common in Egypt from the earliest to the latest period *—one formed of vast rectangular blocks of stone laid in parallel courses, the other of sun-dried brick. The latter was used for walls of towns and sacred precincts, and occasionally for pyramids, but never for any part of a temple.

The stone walls were of prodigious thickness and the blocks of gigantic size; but in the early Theban works we find little of that interlacing of the stones, or *bond*, which is so essential to stability. This partly accounts for the ruined state of some of those tremendous masses—gigantic walls of the most massive construction, and absolutely rent asunder. The masonry of the pyramids, however, appears to be excellent. Unlike the migratory Pelasgi, to whom reference has already been made, the Egyptians seem to have used mortar from the earliest ages. The blocks were also commonly united by wooden dovetailed cramps about a foot in length.

The columns ordinarily employed were of such colossal dimensions that they were necessarily *built up*—each cylindrical layer being composed of several stones. They were commonly constructed with blocks rough-hewn externally; the shaft was afterwards finished, and the capital chiselled to the proposed design. A whole rough-hewn colonnade is still to be seen in the isle of Philæ.

Walls appear to have been left rough till they received their sculpture, and Herodotus † intimates that a similar method was followed at the Great Pyramid: having been carried up to the full height, it was finished off from the summit to the base.

Mr. George Godwin, in his admirable "History in Ruins," says:—"The most ancient structure remaining is the Great Pyramid—one of those mighty works wherein, as Dénon says, men seem to measure themselves with Nature. Herodotus, who visited Egypt about 450 years before the Christian era (some say 500), or more than 2,300 years ago, spoke even then with uncertainty as to its date. It is, however, usually ascribed to Suphis (or Cheops), who reigned soon after Menes, and may be called 4,000 years old—Bunsen says 5,000."

Herodotus says: "The ascent of the pyramid was regularly graduated by what some call steps, and others altars. Having finished the first flight, they elevate the stones by the aid of machines constructed of short pieces of wood; from the second by a similar engine to the third; and so on to the summit. The summit of the pyramid was first of all finished; descending thence they regularly completed the whole"—that is, they placed plates of stone slantingly from one step to the other, and so produced a uniformly slanting mass.

The dimensions of the Great Pyramid have been differently stated, the mounds of rubbish rendering it difficult to obtain accurate measurements. Those taken by Colonel Vyse's operations in 1837, probably nearest the truth, are as follow:—Original base, 764 feet; actual base, 746 feet; original inclined height, 611 feet; actual perpendicular height, 450 feet.

The original perpendicular height, therefore, supposing the pyramid to have been carried up to a point, was about 480 feet, or 43 more than St. Peter's at Rome, and 110 more than St. Paul's Cathedral, London. The area covered was almost 13½ acres, but the approximate size of the mighty mass will be better understood if it is described as a solid pile, the base of which would occupy the whole square of Lincoln's Inn Fields, and the height of which would exceed that of St. Paul's. The stones employed in the construction vary from five to thirty feet in length, and from three to four feet in height.

According to Pliny,* 366,000 men were employed on its erection for twenty years, and Herodotus tells us that an inscription on the exterior stated the expense of providing them with radishes, onions, and garlic amounted to 1,600 talents of silver (£345,600). Ten years were employed in making the road through which the stones were to be drawn, the quantity of which Colonel Vyse estimates at 3,316,000 tons.

Thus thousands of enormous stones, all accurately squared and adjusted, were here elevated to hundreds of feet above the ground, and each was hoisted up step by step, until it reached its bed.

The Pyramids, however, although they attest the resolution of the founders, reflect but little honour on the Egyptian nation. One can scarcely contemplate these structures without the conviction that they were the work of an enslaved and driven race. Such vast piles of mere stone and mortar could never have been reared in Greece or Rome. At the Parthenon or at St. Peter's you view the result of the labours of a multitude of ingenious and thinking men, each contributing the skill derived from a life devoted to his art; but in the erection of the pyramids little else was required of the artificers than physical exertion and obedience to the taskmasters—and, indeed, nothing was done for the labourers which could elevate or educate them. All we find in relation to the workmen is a record of the amount spent on onions for them!

How different this from the present age, when all civilised nations are vying with each other in the promotion of the instruction, the mental improvement, and social well-being of the working classes!

The first material used by the Greeks in their buildings was timber. They then employed bricks, the art of making which they learnt from the Egyptians; common stone followed next; and when they had accomplished the complete glories of their style, they adopted marble. The sort called Parian was the most admired, but this was principally used in sculpture. Pausanias also tells us that in the earlier times several temples were built of *bronze*. Stones of immense size, after the manner of the Egyptians, were also used by the ancient Greeks. In later periods smaller stones were used; these were of various forms, having in some cases four, and in others five or six sides, and were joined with the utmost care and nicety.

As architecture and other arts advanced, the Greeks used cubical and oblong stones, with which they constructed their

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* Wathen's "Arts and Antiquities of Egypt."

† Herodotus, a celebrated Greek historian born at Halicarnassus in 484 B.C. and died 408 B.C.

* Caius Plinius Secundus, a great Roman writer who lived in the first century. He was suffocated by the vapours caused by the eruption of Mount Vesuvius, A.D. 79.

walls, says Vitruvius,* in two principal methods—one called *isodomon*, in which all the courses were of an equal thickness; and the other *pseudisodomon*, in which they were all unequal. The first, or true manner, was always used in their grandest buildings, as being the most beautiful; and the latter, or false method, where beauty of appearance was of less consequence.

Another and still inferior mode of walling was also used by the Greeks for works of lesser consequence; this was called *emplecton*. The front stones only of this manner were wrought, and the interior left rough and filled in with stones of various sizes or rubbish. This style was principally used in walls of great thickness, such as those surrounding cities. In some instances the walls were built of bricks or common stone, and faced with marble.

Cement was seldom used by the Greeks in their best works, as the size and weight of the blocks and the great exactness with which they were squared were sufficient for solidity, and of course made more perfect and complete joints.

The Greek architects of the best period were judiciously careful that the ornamentation should in every case accord not only with the purpose to which the building was to be devoted, but that it should be appropriate to the situation in which it was to be placed. Thus they never built a prison in the Corinthian (or most graceful and highly decorated) style, nor a theatre in the severe and solemn Doric. The external ornaments are bold and sparingly distributed, and as they are to be exposed to light, they stand out in high relief from the surface, so as to cast bold shadows. This is called *alto-relief*, whilst the system of ornamentation used for less exposed situations was that called *bas-relief*, in which the figures or objects project only partially from a flat surface, like a raised painting. Both of these styles may be studied from the model of the Parthenon, or Temple of Minerva, at the Crystal Palace, in which the ornamental sculpture will be observed in its place, whilst a portion of it is placed of the size of the originals along the walls of the gallery. The originals, called the Elgin Marbles, may be seen in the British Museum. Amongst these will be seen several figures—such as Theseus, Hercules, and Ilissus, a river god, which formed portions of the groups in the pediment, or triangular portion surmounting the pillars of the portico. These were absolutely separate from the background. (Figures placed in this manner may be seen in the pediment of the Royal Exchange, which faces the Poultry, London.) The Elgin Marbles† also comprise the celebrated Frieze—a broad horizontal band of sculpture which was placed around the outer wall of the *cella*, or principal chambers of the temple, within the cloister or covered walk which surrounded the building. This remarkable work represents the solemn procession to the temple of Minerva during the Panathenæan festival, and has never been equalled for elegance of composition and the variety and gracefulness of the figures. It is executed in low relief, in order to adapt it for its precise position; for as it was placed high up on a wall, in a narrow corridor, the lower part of the figures would, had they stood out in a high relief, have hidden the upper from the vision of the spectator, who was precluded from stepping back to view them at a distance; and, further, the frieze, placed as it was within the colonnade, received its light from between the columns, and by reflection from below, and therefore figures projecting far from the background would have cast shadows in an uncertain or contradictory manner.

This exquisite frieze occupied slab after slab, a space of 524 feet in length. The remains of it in the British Museum, on slabs and fragments of marble, are to the extent of 249 feet, besides 76 feet in plaster casts. These sculptures were designed by Phidias,‡ and were executed by him, or under his superintendence.

The masonry of the Greeks was, as has been said, executed in the most beautiful marble, the workmanship being worthy of the costly material; the joints, etc., being worked with the most exquisite refinement and truth, whilst the artistic work has not been surpassed in any subsequent period. "It seems difficult to believe," says Mr. Ashpitel, "that so enlightened a people were ignorant of the use of the arch, especially as it is clear that it was known not only to the Egyptians, but was used in Nineveh. However, no example of a Greek arch exists at this time as an architectural feature, although for necessary purposes (as covering drains) and concealed in the walls (as discharging arches) examples are to be found in Greek works. It is probable that, as they had plenty of marble in blocks of almost any size, they preferred to use it in horizontal bearings to working it into arched forms."

* Vitruvius, a celebrated Roman architect, born about 80 years B.C. (see TECHNICAL EDUCATOR, Vol. I., p. 39).

† The Elgin Marbles were brought from Greece by Thomas, seventh Earl of Elgin, and purchased from him by the nation for the British Museum in 1816 for the sum of £36,000.

‡ Phidias, a famous sculptor of Athens. He died B.C. 432.

AGRICULTURAL CHEMISTRY.—IX.

BY CHARLES A. CAMERON, PH.D., M.D.,

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CHAPTER IX.—PHOSPHATIC MANURES.

THE phosphatic manures employed chiefly in these countries are bones, guano, and superphosphate of lime; but the manufacturers of artificial manures employ as raw materials various mineral and organic phosphates which the farmer does not use directly for manurial purposes.

Bones consist of organic matter (chiefly gelatine), which is combustible, and mineral substances, which are incombustible; they also include a considerable amount of water. By boiling bones by far the greater portion of their fatty constituents and a proportion of their gelatine are removed. When kept for some months after being boiled their composition is generally found to be nearly the following:—100 parts of dried boiled ox-bones contain—

Moisture	10
Organic matter	28
Tricalcic phosphate (bone phosphate of lime)	54
Magnesic phosphate	2
Calcic carbonate	4
Alkaline chlorides and sulphates	1
Insoluble matters	1
	100

When the bones are fresh or "green" they often contain nearly half their weight of water. It is always the more economical plan to buy the very driest bones, even if they are apparently very dear. Ox-bones appear to be better than sheep-bones, whilst the latter are considered superior to horse-bones, at least for manurial purposes.

The amount of nitrogen in bones is considerable, and is sometimes equivalent to nearly 5 per cent. of ammonia. On the average, I have, however, found in commercial bone-dust only from 2·5 to 3·7 per cent. of nitrogen. During the decay of bones in the soil the nitrogen is chiefly converted into ammonia —fourteen parts of nitrogen uniting with three parts of hydrogen (which is also a constituent of bones) form seventeen parts of ammonia.

As fat is a useless addition to the soil, bones should be boiled to deprive them of their grease; the value of the fat should more than compensate for the cost of boiling the bones. The liquid in which the bones are boiled contains, after the removal of the fat from it, an important amount of nitrogenous matter; this liquid should therefore be preserved, and added to the manure-heap.

The bones met with in commerce are often grossly adulterated with gypsum, coprolites, sand, and marl; and I have found so much as 50 per cent. of extraneous matter in bone-dust. "Half-inch" bones are less liable to be adulterated than quarter-inch; whilst unbroken bones cannot readily be tampered with without detection. Large bones deposited in the soil remain there for very many years before they undergo complete decomposition. When they are reduced to very small fragments, by means of the bone-mill, they are rendered far more active as a fertilising agent. Under any circumstances, however, bones are a slowly-acting manure, and are best adapted for pastures, where fertilising matters need only be slowly applied. The action of bones may be hastened by fermenting them before their application to the soil. The bones should be mixed with half their weight of earth, piled up into a heap, and kept saturated with the strongest liquid manure from the house. In about three or four weeks the bones will be found thoroughly fermented, and their hard structure softened. The late distinguished agriculturist, Mr. Philip Pusey, whilom President of the Royal

Agricultural Society of England, employed fermented bones in green crop husbandry with remarkable success. He believed himself to be the inventor of this method of treating bones, but in this respect he was mistaken, as it was practised, though rarely, many years before his experiments were undertaken. Bones subjected to the action of high-pressure steam decompose much more readily in the soil than the finest bone-dust; but steamed bones are very rarely used as a manure.

In South America the bones of oxen and other animals are burnt upon a very large scale; and the incombustible residue is, under the name of bone-ash, largely exported to Europe, where it is chiefly employed in the manufacture of artificial manures. This substance contains from 68 to 76 per cent. of tricalcic phosphate, the average proportion being 71 per cent. The other ingredients are moisture, calcic carbonate, alkaline salts, carbon, and insoluble earthy matters. Farmers very rarely use bone-ash as a manure *per se*; but it is one of the commonest sources of phosphates used in the manufacture of superphosphate of lime and other artificial manures.

In the chapter on guanos, I referred to those which contain but a trace of nitrogen, and which are only valuable on account of their phosphates. The following table shows the average composition of some of the phosphatic guanos now in the market:—

COMPOSITION PER 100 PARTS OF PHOSPHATIC GUANO.

	Maldon Island.	Mejilores.	Pacific	Howland's Island.
Moisture	10·0	10·0	9·5	16·0
Organic matter and ammoniacal salts	9·0	7·5	14·0	8·0
Containing nitrogen, equal to ammonia	(0·05)	(trace)	(0·30)	(0·40)
Tricalcic phosphate	73·0	75·0	40·0	73·2
Calcic sulphate (gypsum)	3·0	—	—	—
Calcic carbonate (chalk)	4·0	—	30·5	—
Alkaline salts	0·5	5·5	3·3	2·5
Insoluble matters	0·5	2·0	2·7	0·3
	100·0	100·0	100·0	100·0

In the year 1840, Baron von Liebig, in his celebrated work on "Agricultural Chemistry," suggested that the fertilising action of bones might be greatly hastened by treating with sulphuric acid. This admirable suggestion was shortly afterwards carried into effect by Mr. Lawes, of Rothampstead; and it has been the means of creating a new and extensive branch of manufacture in these countries and in other parts of the world—I refer to the manufacture of superphosphate of lime, and other manures of the kind. As I have already explained, bones dissolve slowly in the soil, because their constituents are in a hard and firmly coherent state, and in coarse fragments. By Liebig's process the bone ingredients, but more especially the phosphates, are rendered soluble or pulpy, in which state they are readily dissolved by the solvents which are present in the soil, and presented in an assimilable condition to the crops.

Bones acted upon by sulphuric acid (oil of vitriol) constitute the commercial article so familiarly known to agriculturists under the names of superphosphate of lime, and dissolved or vitriolised bones. I shall now explain the nature of the changes which take place when bones are converted into superphosphate of lime.

Tricalcic phosphate (familiarly known to farmers as bone, or insoluble phosphate of lime) is composed of three chemical parts or atoms of the metal calcium,* united with one atom of phosphoric acid. This compound is insoluble in pure water, but it is sparingly soluble in water containing carbonic acid, ammoniacal salts, and even common salt. The water which percolates the soil contains the various matters which enable it to dissolve tricalcic phosphate, and the finer the particles of the latter are the more readily are they taken up into solution. When two parts of sulphuric acid are poured upon one part of tricalcic phosphate, the latter parts with two of its atoms of calcium to the acid; the remaining atom of calcium and the atom of phosphoric acid constitute monocalcic phosphate, commonly termed biphosphate or acid phosphate of lime. The two atoms of calcium separated from the tricalcic phosphate, and the two atoms of sulphuric acid form two atoms of calcic sulphate (gypsum, or plaster of Paris).

Tricalcic phosphate is insoluble in water, whilst monocalcic phosphate readily dissolves in that liquid; nevertheless, plants do not take up monocalcic phosphate from the soil, for if they did it would act corrosively upon their tender tissues. The instant monocalcic phosphate is placed in the soil the calcium, which (as chalk) is invariably present in the latter if fertile, unites with the monocalcic phosphate, and converts it into tricalcic phosphate. What, then, it may be asked, is the utility of converting insoluble phosphate into soluble phosphate, when the latter becomes again insoluble when placed in the soil? Simply that the bone phosphate may be got into the finest possible state of division. The most powerful mill only reduces bones to a coarse and hard powder, but the precipitated phosphate formed when soluble phosphate is deposited in the soil is as soft as jelly, and yields easily to the action of the solvents contained in the soil. Tricalcic phosphate contains—

Lime	53·86
Phosphoric acid	46·14
	100·00

According to Berzelius, its composition when derived from bones is, after ignition—

Lime	51·26
Phosphoric acid	48·74
	100·00

It requires 156 parts of tricalcic phosphate to produce 100 parts of monocalcic phosphate. Every part of biphosphate of lime as a manure is equal to 1·56 parts of bone phosphate made soluble.

100 parts of boiled bones and 35 parts of brown oil of vitriol, thoroughly mixed, and allowed to remain for a month, usually have the following composition per 100 parts:—

Water	16·0
Organic matter and combined water	20·0
Containing nitrogen, equal to ammonia	(2·0)
Biphosphate of lime	18·0
Equal to bone phosphate made soluble by acid	(28·0)
Phosphate of lime	8·0
Sulphate of lime	35·0
Alkaline salts	1·5
Insoluble matters	1·5
	100·0

This manure would be rather damp, and should be dried with peat-mould or fine clay.

1 ton of bone-ash acted upon by 18 cwt. of brown sulphuric acid will produce about 38 per cent. of soluble (not *biphosphate*) phosphates.

There are several minerals which contain large proportions of phosphoric acid. *Phosphorite* is a white, hard stone, containing upwards of 70 per cent. of the tricalcic phosphate. The white mineral termed *apatite* is a compound of three atoms of tricalcic phosphate with one of calcic chloride and one of calcic fluoride; the green mineral termed *moroxite* has a similar composition. The brown pebbles found in large quantities in various places in the east of England, and termed coprolites (from the erroneous idea that they were the fossilised excreta of extinct species of animals), consist of from 50 to 60 per cent. of earthy phosphates, mixed with calcic carbonate and fluoride, and insoluble earthy matters. Enormous quantities of coprolites have been raised in England during the last thirty years, and their use has tended greatly to economise the production of superphosphate of lime. Phosphate of aluminium is likely to be soon largely employed in the preparation of artificial manures. Mr. Spence, of Manchester, has recently patented a process whereby he proposes to convert the alumina in the phosphate into alum, and its phosphoric acid into superphosphate of lime. I have examined the native phosphate of aluminium which Mr. Spence proposes to use in his process, and I find that it contains phosphoric acid equal to nearly 70 per cent. of tricalcic phosphate.

Mineral superphosphate is prepared by pouring sulphuric

* Calcium and oxygen in union constitute quick or burnt lime (calcic oxide).

acid (specific gravity 1·6 to 1·7) on phosphorite or coprolites. The phosphate of calcium in such minerals as coprolites is useless; it should, therefore, be wholly converted into soluble phosphate, so that not the slightest portion of insoluble phosphate should remain. For every per cent. of chalk in the coprolites, 1 per cent. of sulphuric acid (specific gravity 1·7) should be used; and for every 10 per cent. of earthy phosphate, 8 per cent. of acid. As deleterious fumes are given off during the mixture, the process is conducted in a close chamber, provided with a flue to convey the gases and vapours into a chimney. The coprolites are ground into a powder before being used, and the finer the powder is the more readily does it yield to the action of the acid. When the superphosphate is made it is always found in a hard mass, and it must be broken up by a pick or spade. In manure factories there is a machine called a disintegrator used for this purpose. On a small scale, coprolite or bone superphosphate may be made in a wooden tank, 12 feet long, 5 feet wide, and 2 feet deep. To protect the wood from the action of the acid, the inside of the tank should be coated with pitch.

Although the price of superphosphate of lime is generally about £7 per ton, the composition of the article varies considerably, some specimens being nearly twice as valuable as others. It is necessary, therefore, that the farmer should never purchase superphosphate of lime, or any other kind of artificial manure, without receiving a guaranteed analysis, showing its composition. A good bone superphosphate should include from 22 to 26 per cent. of soluble phosphates (bone phosphate made soluble) to 14 per cent. of insoluble phosphates, and from 1·2 to 2 per cent. of ammonia. A mineral superphosphate should include from 26 to 35 per cent. of soluble phosphates; any insoluble phosphate which it may contain being considered worthless.

In purchasing a manure the farmer has to consider the cheapest sources from which he can obtain soluble phosphates, insoluble phosphates, and ammonia. I have drawn up the following table of the money value of the different ingredients of manures, founded upon the prices at which they may be obtained at present from the cheapest sources :—

MONEY VALUES OF THE CONSTITUENTS OF MANURES.

	Per ton.		
Ammonia	£80	0	0
Biphosphate of lime*	30	0	0
Phosphate of lime	10	0	0
Sulphate of lime	1	10	0
Alkaline salts (soda and potash compound mixed)	2	0	0
Potash salts	16	0	0
Organic matter	0	10	0

Recently manufacturers have not been able to obtain sulphate of ammonia under £16 to £18 per ton. This salt contains 25 per cent. of real ammonia; and, therefore, in it the farmers may purchase ammonia at the retail price of £80 per ton.

Biphosphate of lime is of equal value to the farmer, whether prepared from bones, bone-ash, or coprolites. It cannot, however, be produced as cheaply from guano or bones as from minerals; but that is a matter which concerns the producer and not the consumer of soluble phosphates. The manufacturer can procure phosphate of calcium at £6 per ton in coprolites; whereas it costs him £8 10s. per ton in bones (allowing for the value of their other ingredients), and £9 15s. per ton in phosphatic guanos. But why make soluble phosphates from bones or guano? Bone-soluble phosphate is precisely the same thing as coprolite-soluble phosphate; no chemist could discover the slightest difference between them, for there is none. Therefore, in even the so-called bone superphosphate, the biphosphate should be derived from a mineral source; whilst the insoluble phosphates should be in the form of bone-dust, or soft guano.

The farmers can purchase insoluble phosphates in bones or bone-ash, at about £10 per ton; but if they buy phosphatic guanos, they pay from £13 to £15 per ton for the phosphates which they contain. Although guano phosphates are soft, and probably dissolve pretty readily in the solvents in the soil, I consider the price at which they are generally sold beyond their real value; and farmers would act wisely if they bought their ammonia in the form of sulphate of ammonia, their soluble phosphates as a mineral superphosphate, containing 30 per cent. of biphosphate, and their insoluble phosphates in the form of bones or bone-ash. 1 cwt. of sulphate of ammonia, 4 cwt. of the finest bone-dust or fermented bones, and 15 cwt. of concentrated mineral superphosphate would form a compound containing 2 per cent. of ammonia, 23 per cent. of soluble phosphates, and 10 per cent. of bone phosphate, and costing less than £7 per ton.

A simple way in valuing a manure is to regard the 100 parts in the analysis as 100 tons. The amount of each ingredient is multiplied by the price per ton; all the products added together give the value of 100 tons; the result divided by 100 gives the value of 1 ton. Suppose a manure contains 1 per cent. of ammonia, 20 per cent. of biphosphate of lime, and 5·5 per cent. of phosphate of lime; then

	£	s.	d.
1 ton of ammonia, at £80	80	0	0
20 tons of biphosphate, at £30	600	0	0
5·5 tons of phosphate of lime, at £10.	55	0	0
	£735	0	0
Divided by 100, this gives per ton	£7	7	0

* I give these compounds the names by which they are familiarly known to agriculturists. Their strictly scientific designations have already been explained.

BUILDING CONSTRUCTION.—XIX.

STAIRCASES.

In our lessons on "Building Construction" we have touched on the methods usually adopted in the structure of walls and roofs, and the formation of every important part of a building, and we now come to staircases, by which we obtain the means of ascending and descending with ease and readiness from one floor of a building to another.

The rudiments of the staircase are to be found in the common ladder, formed of two parallel lengths of wood or a fir-tree sawn in half, connected by horizontal bars of wood or "rungs," from a foot to eighteen inches in length, and it may be remarked that nothing more than a ladder is frequently used even now for reaching a hay-loft or harness-room from the stable or coach-house below. When it was found that it was inconvenient and indeed almost impossible to ascend the ladder without grasping its sides by the hands, broad pieces of timber were substituted for the sides of the ladder, into which other broad pieces were inserted at a certain angle, so as to present a level surface when the whole contrivance was reared against a wall. This next step in the formation of a staircase may be readily recognised in the "steps" found in almost every household, and used for cleaning windows, walls, and a variety of other purposes. The transition from this to immovable flights of stairs, such as are now used in houses and buildings of every description, can be easily traced, and it is only necessary to point out that the staircase in course of time developed into an architectural feature of great beauty, as may be seen in many of our old English mansions and public buildings.

The construction of staircases is considered the highest branch of joinery, and the drawing connected with them requires much attention.

Staircases may be divided into—(1) Geometrical, or such as are supported by or against a wall; (2) Bracket stairs, or such as are built in an opening or well, with strings and newels, and are supported by landings and carriages, the brackets mitreing to the end of each riser; (3) Dog-legged stairs, which have no well-hole, the hand-rail of the progressive and the retrogressive flights falling in the same vertical plane.

The steps are fixed to *strings*, *newels*, and *carriages*; and the ends of the steps of the inferior kinds terminate only in the side of the string, without any "housing."

Fig. 182 is the plan, and Fig. 183 is the sectional elevation of a dog-legged staircase, with two-quarter winders—that is, the two spaces at A and B, instead of being used as a landing, are divided into winding steps. In the plan, *a* is the seat of the lower newel, and *g* is the seat of the upper newel. The dotted line represents the faces of the risers—that is, the upright portion of the steps; and the full lines are the plans of the

surfaces of the steps, called the "tread." The edges of the steps are termed the "nosings."

In the elevation, A is the lower and B the upper newel. The upper part of each is generally turned, but is here, for simplicity, rendered necessary by the small size of the illustration, drawn as if square. C and D are the lower and upper string-board, framed into the newel.

In the setting out of staircases a *storey rod*, R S, is used. This is a very necessary article, and consists of a rod or rule, of the gross height of the complete storey, or from the upper surface of the boards of the one floor to the under surface of those of the other. It is divided into as many equal parts as there are to be risers, and from these the heights of the steps are to be gauged. In the construction of dog-legged staircases, the first thing is to take the dimensions of the stair and the height of the storey, and to lay down a plan and section, representing all the newels and steps, upon a floor, to the full size, or certainly to as large a scale as possible. Then the situations of the carriages, pitching-pieces, long-bearers, and cross-bearers will be ascertained, as also the string-boards; and the quantity of room required by the stairs at nine inches tread and six inches rise, as the case may be, will determine whether there are to be

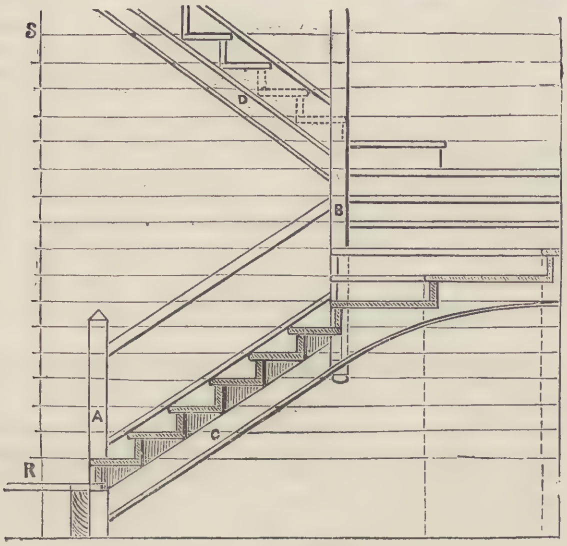
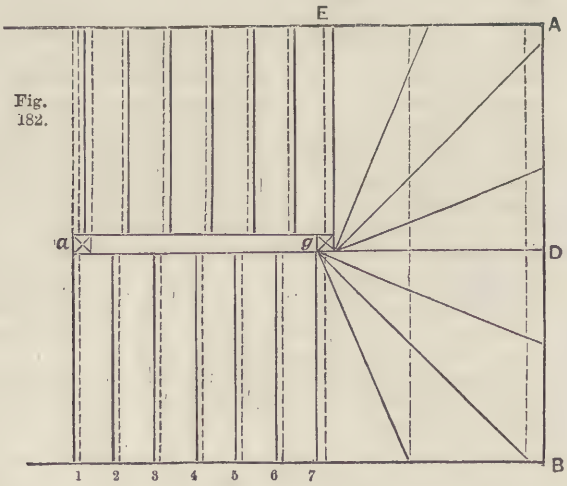


Fig. 183.

Fig. 182.



quarter-paces, half-paces, one-quarter winders, or two-quarter winders.

In drawing this example, or others of a similar character, having drawn the rectangle, which is the plan of the well in which the staircase is to be built, divide it longitudinally into two equal parts; on each side of the dividing line set off half the width of newels and hand-rail. This will leave the space on each side which is to be occupied by the stairs.

Draw lines *a* 1, 2, 3, 4, 5, 6, 7; produce line 7 across the width of the baluster, and produce the line of the baluster until it reaches D; the newel will then occupy the right angle formed at *g*. Complete the plan of the newel, and produce the line of its face to E.

It will be seen that E A is equal to the length of the stairs, and that this is the case with D B; but that A D and B 7 are increased beyond a square by the addition of the thickness of the newel *g*. This will be clearly understood on referring to the drawing.

Now divide this rectangle into the number of equal parts required for the winders, and draw the edges of these radiating from the angles of the newel. From E set off the upper flight of stairs, and thus complete the plan.

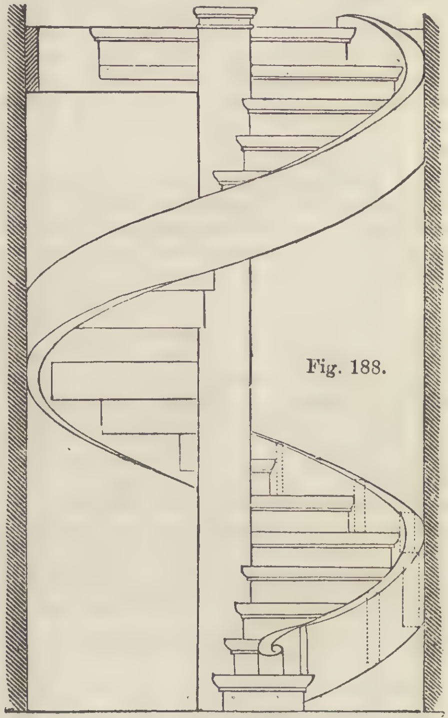


Fig. 188.

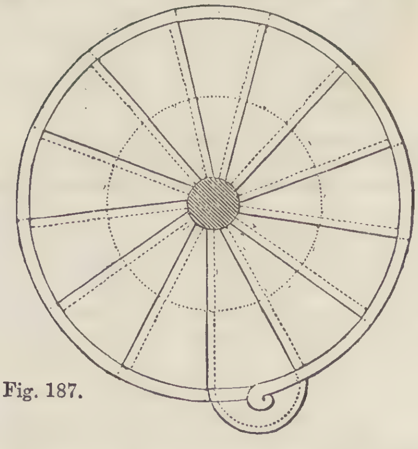


Fig. 187.

In commencing the elevation draw a ground-line, and project the line of the wall from A B in the plan. Draw the storey-rod, S R, and set off on it the heights required by the steps, and draw horizontals from each of these points; intersect these by perpendiculars drawn from 1, 2, 3, 4, 5, 6, 7 in the plan, and the points obtained by the intersections of these two sets of lines will give the edges of the stairs in the elevation. It will be seen that the points for the winders are obtained by drawing perpendiculars from the points where the edges of the winders in the plan cut the wall.

Next project the lower and upper newels, A and B, from a and g in the plan, and it will be seen that the lines of the hand-rail and string-board are parallel with a line drawn touching the edges of the stairs. Having drawn these, the arc forming the underneath line of the winders will complete the figure.

Fig. 184 is the plan and Fig. 185 is a section on the line A B of a staircase, with landing at half the height of the flight, and a narrow well between the ends of the stairs. The landing rests on three joists, a, a, a, which are stiffened by the cross-pieces, b, b.

The balusters and hand-rails are omitted in the section in order that the drawing may be rendered as simple as possible.

This study is to be worked on the same system as the last, the section being projected from the plan. It will be seen from the plan that the string-board turns at the end in the form of a semicircle; but although it turns *round* a semicircle, it must be remembered that it is at the same time *rising* to the next flight, and the curve it thus forms in the sectional elevation is a portion of a helix. In a drawing of the size of the example this curve might be drawn by the eye, but the power of doing this must be acquired by studying the true construction of the curve on a larger scale.

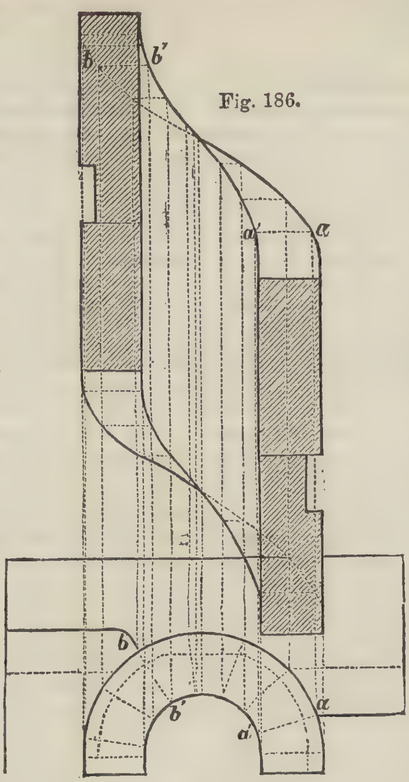


Fig. 186.

For the construction of the helix curve on which this figure is based, the student is referred to lessons on "Projection."

Fig. 186 represents the plan and elevation of the portion of the string-board under consideration, projected on a plane parallel to the steps in the example (Fig. 184).

Having drawn the outer semicircle, $a\,b$, and the inner semicircle, $a'\,b'$, divide either into any number of equal parts, and draw radii; divide the height which the curve is to ascend into the same number of equal parts, and draw horizontals.

Draw perpendiculars from the extremities of the radii, and their intersection with the horizontals will give the points through which the helices representing the winding round a semicircular space will be developed.

Fig. 187 is the plan and Fig. 188 is the elevation of a winding staircase with solid central newel. In the plan, the dotted lines represent the plans of the risers, and from these, therefore, the perpendicular edges of the stairs must be projected; whilst the nosings of the steps are to be projected from the full lines in the plan. The student who has worked the previous figures will not, it is presumed, require any further instructions in drawing this subject.

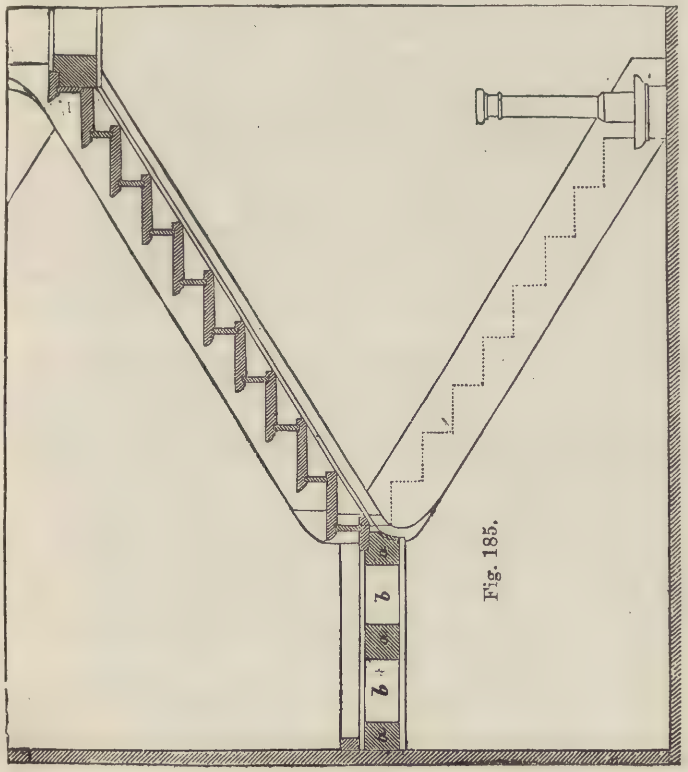


Fig. 185.

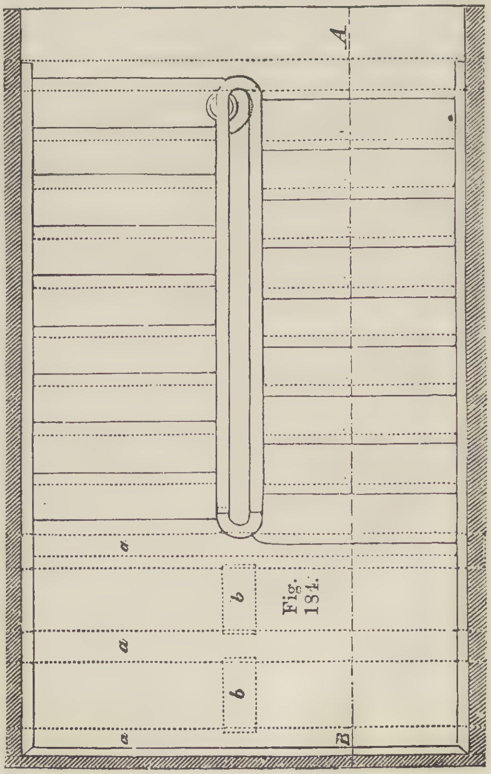


Fig. 184.

SANITARY ENGINEERING.—IV.

PRIVATE GAS-WORKS.

In our previous papers we have given some account of the method of gas manufacture for public companies—the comparative merits of different descriptions of burners—and in the last, on Photometry, of the manner in which comparison was instituted between various methods and materials for lighting purposes; quoting a few figures which clearly showed that gas was the cheapest of all. On its first introduction, at the begining of the present century, all gas-works were private, as there were no public companies; and now, after the lapse of a generation, the idea appears to be dawning upon the public mind, and to be generally received, that where the demand is sufficient in amount, and the other requisite facilities exist as to room, convenience, administration, etc., it is cheaper to *make your own gas* than to purchase it of a company. The process is in any case the same as generally described in our first paper upon the subject, and many engineering firms have recently turned their attention to the subject, with the view of producing sets of apparatus for the manufacture of gas in comparatively small quantities, as required for warehouses, for private mansions, or even for dwelling-houses. One firm alone has fitted up more than 600 sets of gas apparatus in various parts of the United Kingdom, and we propose to give the detail of one or two of these arrangements. One of the leading questions bearing upon the subject is, of course, that of price. Take London as an instance: 3s. 6d. per 1,000 cubic feet is an ordinary price for gas, and we may say without fear of contradiction, that it has been ascertained by repeated experiment, that under all ordinary circumstances the cost of the gas thus supplied, as far as the manufacture pure and simple is concerned, does not exceed 2s. 6d., thus leaving a margin of nearly 30 per cent. in favour of the man who makes his own gas. Where is the difference? In the immense outlay of capital already incurred by many of the companies in the earlier and less experienced stages of their existence, before the subject was so well understood as it is at the present time; in the large and expensive staff required for working and collecting; and above all, in the fearful per-centage of waste by leakage, condensation, etc., necessarily incurred in forcing the gas through lengths of piping of various sizes, extending over many miles of ground. The actual value of this last item is usually roughly calculated at 20 per cent.—that being the figure usually accepted—but probably a much larger figure would be nearer the truth.

In many country districts there is no public gas company within reach, and here the advantage, where the consumption warrants the necessary expenditure, of the erection of private gas-works is of course incontestable. Noblemen and gentlemen throughout the country are beginning to appreciate the advantages (which appear, indeed, to be very obvious) of the system, and we may instance some country seats of the highest class, where private gas-works have been erected: Bayham Abbey, for the Marquis of Camden, in the neighbourhood of Hawkhurst in Kent; Cliveden, the seat of the Marquis of Westminster, situate within a short distance of Maidenhead; Madresfield Court, near Worcester, for Earl Beauchamp; and the Grange, Alresford, for Lord Ashburton. Indeed, we have no doubt that in the course of a few years no country seat of any magnitude will be without its own gas-works, the advantages of economy and convenience being incontestable.

Coal is by no means the only material available for the manufacture of gas, though, of course, it is the most commonly employed. Peat has been utilised for the purpose, and by means of proper apparatus specially constructed, a gas of tolerable illuminating power has been obtained. In Bavaria, Professor Pethenkofer has introduced a process for the re-distillation of turf-tar, which has been extensively adopted; and in some parts of France, the refuse of manufactories, treated chemically with acid, has been profitably employed for the same purpose, thus utilising a material which had been previously considered utterly without value.

Petroleum is also a leading material among those from which gas may be made; the necessary apparatus being provided, gas can be made from it which possesses about three times the illuminating power of ordinary coal-gas, its cost, however, being greater in somewhat a like proportion; a special adaptation of burners, etc., is required for the consumption of these highly illuminating hydro-carbon gases, as if burnt by means of the ordinary media considerable waste is the result. We have heard of gas obtained from some of these oils which has a lighting power expressed by 30 candles, the gas of ordinary consumption being of about 15 candle-power. A reference to our paper on Photometry will explain what these figures mean, and how the results are ascertained and tabulated. Although these results have been experimentally obtained, commercially the question has not yet assumed sufficient practical development for us to recommend with confidence the adoption of this comparatively new process.

And now to give some idea of the facility that exists for the manufacture of gas by private firms: we may say that a complete set of gas apparatus may be procured for £50, which will supply the ordinary quantity required for 10 to 15 lights; they are made portable, of iron of course, and can be fixed in a space not exceeding 100 feet superficial, or 10 feet square. The first portion is the retort in which the coal is burnt, in a small apparatus like that in question producing about 40 cubic feet of gas from each charge. Iron cases, furnace-doors, shifting lids, hoops, etc., are all included; and the interior of the retort is generally lined with what are technically called fire-lumps—*i.e.*, bricks of a nature that will resist the action of intense heat, and which can be procured ready moulded to any required form. The next process is the condensing, washing, and purifying, the same for small quantities as for large, and all effected in a combined apparatus specially designed for the purpose. The last requirement is the little gas-holder, to contain from 100 to 150 cubic feet of gas, which is made of wrought plate-iron, provided with its small columns, balance weight, etc., as complete in its way as the huge gas-holders that form the distinguishing feature of all gas-works as seen from a distance.

The practical difficulty with these very small sets of apparatus is, of course, the attendance. If the proprietor have sufficient scientific knowledge to instruct a servant to attend to them, in which case he must thoroughly understand the detail of each portion himself, they may probably be introduced with advantage; but if this is not the case, as for so small a consumption it is not worth while to employ an engineer, probably the best course would be, if gas is so accessible, to obtain it from a public company. We have only described this very small apparatus in order to show into what detail it is possible to go upon the question.

The limit, we take it, of the point at which it becomes desirable from a commercial point of view to introduce private works, is that where the consumption is sufficient to warrant the engagement of one competent man who thoroughly understands the process, and can take entire charge of the gas-works; and to give an idea of the outlay required, we subjoin somewhat in detail the requirement for the supply of 1,000 burners for 8 hours; this we take to be about the limit probably necessary for a very large manufactory. We may mention that the details are taken from a specification that has been actually carried out; the portions resolve themselves, of course, as before, under the heads of (1) the retort, (2) the purifier, (3) the gas-holder. The cost of the whole, including packing-cases, but exclusive of fixing, delivered in any part of England, may be taken at £1,200.

1. *The retort*, consisting of 18 cast-iron D-shaped retorts, each 7 feet long, 14″ × 12″, mouthpieces and lids for ditto; ears, cross-bars, and T-screws as required; 4 furnaces, of 12 bars each; furnace-doors, frames, etc., as required; 4 evaporating pans, sigh-boxes and covers; hydraulic main, 14″ diameter; ascension-pipes or stand-pipes and flange dip-pipes; tar-pipes to cistern.

2. *The purifier.*—Patent combined apparatus—Bower's in this case, though there are several others, forming in one vessel the condenser and scrubber; with 4 dry-lime purifiers; centre charge-valve and a double bypass-valve; 6 tiers of cast-iron sieves on wrought-iron T-bars; 5 wrought-iron lids, air-plugs, eyes and keeps; syphon boxes, cleaning doors; water spreader, etc. etc; small travelling crab, on girders, for moving various parts of apparatus.

3. *The gasholder*, 50 feet diameter by 15 feet deep at the sides, to contain 30,000 cubic feet; the crown of 15, the sides of 16 gauge thickness (this alludes to the ordinary method of measuring the thickness of sheet iron—viz., what is called the Birmingham wire gauge); and 6 cast-iron guide columns,

trussed girders, foundation plates, and all other necessary appurtenances.

It would, of course, be possible to describe all these matters in complete detail, but that would be beyond the limits of the space at our command, our object being only to give one or two instances of the way in which the commercial question has been elaborated, and the facility that exists of obtaining a complete set of apparatus for private gas-works. We should state, however, that the price quoted for the last set of apparatus includes no provision for setting or building work, but only expresses the first cost of the items to be procured; all these additional matters of expense will, therefore, be regulated by locality and similar circumstances; and it is of the utmost importance that any undertaking of the magnitude of that last described should be carried out under the superintendence of a thoroughly competent and responsible engineer; as otherwise disappointment and failure will be the almost inevitable result.

The two examples quoted may be taken as the extreme sizes, small and large, of private gas-works, the smaller being almost of an experimental character, and perhaps too diminutive for practical use; while the larger size has sufficient power to supply the gas required for public use in a town of from 2,000 to 3,000 inhabitants.

For private gas-works, strictly so called—*i.e.*, those attached to a mansion or a warehouse—perhaps 100 lights is a good average size to take, and without going again into the detail of the various appliances required, which vary only in size and capacity from those already described, we may say generally that the expense of such an apparatus, exclusive of brickwork and fixing, may be taken at £300. When attached to a gentleman's residence, the course usually taken is for the engineer who erects them to instruct one or more of the servants connected with the establishment—*e.g.*, a labourer or an under-gardener—in the details of the daily working; any question of construction or repairs being referred to the engineer. The price of the gas is regulated by the price of coals, and this by the district in which the house happens to be situated; the 2s. 6d. per thousand cubic feet quoted above should perhaps be taken as a minimum.

Good gas can be made from grease and kitchen waste, and a practical gas engineer of our acquaintance has lighted his own residence with gas made from these materials; but the scientific knowledge requisite for their successful manipulation being probably beyond the reach of the major portion of the public, we dismiss the matter with this passing notice.

MINING AND QUARRYING.—VII.

BY GEORGE GLADSTONE, F.C.S.

IRON.

GENERAL DIFFUSION OF THE ORE—PRINCIPAL CENTRES OF WORKS—DIFFERENT KINDS OF ORE—ASSAYING—ANALYSIS.

No metal is so universally diffused in Nature, and that too in such abundant quantity, as iron. This is equally true when applied to almost every country of the globe, but it is our purpose here to confine our attention more particularly to the British Isles, and to those deposits within our borders which are of chief commercial value. At the present time (we do not wish to assert that it will always be so) many rich ores are practically valueless because they are unfavourably situated for reduction, and thus cannot compete with inferior ores which are in the immediate neighbourhood of the smelting works.

The low price of pig-iron, considering the quantity of material (ore, fuel, and limestone) required for its production, limits the trade almost entirely to those districts where all these three ingredients are abundant and cheap. There are some parts of the country, which will be spoken of presently, where iron-works are erected on other than Carboniferous strata; but this is an exception to the general rule, and even there they are favourably situated for bringing the fuel to the works at a very low price. There are, too, some large deposits of ore which are worked, and sent elsewhere to be smelted; but this can only be done advantageously in a few instances where the ore is rich and the cost of carriage is low.

The Weald of Sussex, for instance, contains a great deal of iron ore, and some 200 years ago or more it used to be smelted there; but the circumstances of the trade have altered so much that it cannot be done now. At that time the fuel employed was wood charcoal, but timber is now much too valuable to be used for such purposes, and the iron in those days was many times as dear as it is at present. Were the attempt made to revive the trade by using coal or coke, the cost of the fuel alone, burdened with a heavy carriage, would exceed the value of the iron produced.

The supply of ores is so prodigious that no fear can be entertained of a falling off, for centuries to come, which could affect the price of iron so as to render remunerative again works situated so unfavourably for economical working.

Let us consider some of the principal sources of supply, taking them according to their geographical distribution.

A very remarkable one, both for its extent and its novelty, is the Cleveland district of Yorkshire. It is only within the last twenty-five years that blast-furnaces have been erected for smelting these ores upon the spot—the commencement of an immense trade. The rock here belongs to the Lias formation. The "main seam," as it is termed, extends over an area of about 420 square miles, and varies in thickness in different parts from 3 to 18 feet. This one seam is estimated to contain nearly 5,000,000,000 tons of iron ore. In addition to this there is the "top seam," which covers a lesser area, having in many parts been carried away by denudation, and which is very irregular in thickness, varying from a few inches to 10 feet. These two seams consist of an earthy carbonate of iron, yielding from 10 to 36 per cent. of metal, but affording by their external appearance no indication of their mineral wealth. The ore rather resembles hardened clay, and contains the impressions of numerous shells, principally pecten and avicula, by which names different portions of the main seam are distinguished. The ores of low per-centage are neglected, as the supply of the richer is practically inexhaustible. There is also a still more limited but very valuable deposit, which is a magnetic oxide of iron, containing from 45 to 50 per cent. of metal. These ores are mined very much in the same way as a thick seam of coal would be. Headways are driven, 9 feet wide and 90 feet apart, from which, at intervals of 30 feet, "boards" are excavated 15 feet wide. By this system pillars are left, 90 feet long by 30 wide. When it becomes necessary to work the pillars, they are removed with a loss of only about 10 per cent. of their contents.

Another region, which was the scene of a great revolution in the iron trade in the early part of this century, is the iron district of Scotland which lies south of the Clyde. The coal-field of Ayrshire and Lanark contains a layer of ironstone, known, on account of its dark colour, by the name of "black band," which possesses most singular advantages for its economical working. It is a carbonate of iron, rich in metal, but containing also about 9 per cent. of coaly matter. The crude ore contains from 37 to 40 per cent. of iron, and the presence of coal in the ore enables the preliminary operation of roasting to be done without the addition of other fuel. Since the discovery of this ore the smelting of iron in Scotland has attained an enormous development, and the price of pig-iron has been very greatly reduced through the competition of the Scotch smelters.

In South Wales the beds of coal are almost always associated with bands of ironstone, and, accordingly, almost the whole of that large coal-field is studded with iron-works. It is the great centre for the manufacture of railway bars, which are shipped at the ports in the Bristol Channel to all quarters of the globe. The ore here consists mainly of an argillaceous carbonate, to which the general term of *clay-band* is given, though each layer of importance has its specific name. They are generally thin, but numerous, and contain about 25 to 30 per cent. of metal, with a large admixture of earthy matter, which gives them much of the appearance and colour of hardened clay. On account of this earthy admixture some of the richer ores, which will be spoken of presently, are often imported to mix with them. In the neighbourhood of Pontypool, however, the black band occurs, containing as much as 15 per cent. of carbonaceous matter, and yielding 30 per cent. of metal, an ore very advantageous to the smelter.

The midland counties yield large quantities of iron. So completely is the district between Dudley, Wolverhampton, and Birmingham occupied by this industry that agriculture is almost entirely neglected, and the whole surface of the country is black

with coal-dust and iron slags; while at night it is suggestive of the infernal regions, being illuminated by the flames issuing from thousands of furnaces, and overhung with a lurid pall of smoke. This district has a special historic interest. It was here that Dudley, about the year 1620, first smelted iron with coal; but he thereby produced it at a much cheaper rate than his neighbours, so he and his inventions were not to be tolerated; and it was not till long afterwards, when wood was becoming so scarce that stringent measures had to be taken to prevent its annihilation, that the ironmasters betook themselves earnestly to mineral fuel. This was more than a whole century after the date of Dudley's patent. In our second paper we have spoken of the great deposit of coal in the South Staffordshire field. In some spots the deposit of ironstone is almost as remarkable. The ores here consist of the argillaceous carbonate of iron—the prevailing description in all coal measures—and in some cases the beds attain a thickness of 27 feet. At Wordsley Bank, for instance, the Pennyearth beds are of that depth, and in addition there are 4 feet of "pins." At Brierley Hill these two beds together measure 27 feet. The peculiar names borne by different beds of "stone," which in this part of the country always means ironstone, are sometimes suggestive. "Pin" is a common term, indicative of the ore being in nodular concretions; the Pennyearth is so named because the bed is full of small flattened nodules somewhat resembling pennies. Throughout this district there are other beds of ironstone of varying thickness besides the two named, and the proprietors just select for working at each mine whichever may be the most convenient. The nodular character described above is a very ordinary feature of the beds in the coal measures, and many of these, being very thin, would never pay to work, were it not that other useful material is frequently obtained at the same time. Thus, on reference to Fig. 5 in page 33, where a section of the thick coal in Baremoor Colliery is given, it will be seen that there is a layer of ironstone lying immediately below the "herring coal," and again a second immediately below the "thick coal," and overlying the "first heathen coal." The latter is a very constant bed, varying from 2 to 8 or 9 feet thick, which has been very largely worked. It will be seen from this section that the ironstone and coal can both be got at the same time in these particular instances, so that they would be worth working even if the ironstone bed were very narrow. Again, at other times the iron ore will be close to a bed of fire-clay, and as this is an article of large consumption by the ironmasters, the two can often be profitably worked together. The bands of ironstone are generally very numerous, perhaps twelve to sixteen in number, but only those are regarded as of commercial value which are of sufficient size and richness to be worked for their own sake, or lie in association with the coal or fire-clay. The ores contain on an average about 33 per cent. of iron. When first wrought the argillaceous matrix of these nodules adheres to them, and could not be removed without considerable trouble and expense; but exposure to the action of the weather removes all this, and leaves the nodular concretions free.

To the west of this is an isolated district in which the iron manufacture has been carried on very successfully for a long term of years—Coalbrook Dale. This, again, as its name indicates, belongs to the Carboniferous period. Though the field is of limited area, the works established here possess no little historical interest, as it was here that Abraham Darby, the founder of the great firm that still bears his name, re-introduced the smelting of iron with pit-coal more than 150 years ago.

In North Staffordshire is another deposit of iron, also belonging to the Carboniferous formation, principally the usual earthy carbonates or clay band, containing about 35 per cent. of metal; but near Newcastle-under-Lyme the black band also occurs, containing, in addition, about 10 per cent. of free carbon.

The great coal-field of Derbyshire and Yorkshire also contains large deposits, exclusively of clay ironstone, and averaging about 30 per cent. of iron.

There are some of our most important coal-fields, however, which offer an exception to the rule which has been occupying our attention. Those of the north of England and Lancashire are deficient in these clay ironstones, which are so uniformly present in similar geological deposits in other parts of the kingdom. Not that these districts are without iron ores, but they are very limited in quantity, and of a different character from what has already been described.

In Northumberland and Durham the argillaceous iron ores do not occur in the Carboniferous rocks, but here and there we find spathic carbonates—beautifully crystallised ores—containing a large per-centage (from 38 even to 50) of metal. These are not in the coal measures themselves, but in the Carboniferous limestone, and if found in larger quantity would be of the greatest interest and value, as they yield a very superior iron, this kind of ore being usually free from phosphates and sulphates, which are difficult to separate, and highly injurious to the quality of the metal. An ore of similar character occurs in the Devonian beds of Somersetshire and Devonshire, and being very conveniently situated for shipment across the Bristol Channel to the iron districts of South Wales, these ores are extensively worked for the purpose of mixing with the Welsh.

The other deposits of iron ores of sufficient economic importance to call for special consideration also lie outside the Carboniferous epoch. The first that call for notice are the very remarkable deposits of red hæmatite (anhydrous ferric oxide, Fe_2O_3), which occur principally in Cumberland and the northern portion of Lancashire, and to some extent also in Glamorganshire. A curious feature connected with these is that they occur in large holes or pockets of the mountain limestone, though it is pretty evident that from a geological point of view they do not belong to that period. The red hæmatites commonly occur in crystalline masses radiating from the centre and rounded on the exterior surface, suggestive of the popular name, "kidney ore." At other times they are of an earthy character, but always leaving a very decided red mark; the rouge of silversmiths is, in fact, nothing else than this oxide ground fine. The hæmatites of Ulverstone and Cleator contain the extraordinary quantity of from 60 to 67 per cent. of metal, almost the only foreign matter in the ore being a little silica. Large works are erected for smelting these iron ores upon the spot, but great quantities are shipped also to South Wales and other places to mix with the inferior ores, as hæmatite produces iron of very superior quality. These ores, being found in large masses of irregular form and size, are worked more like a quarry. Near Cleator is a mass about 60 feet thick in some parts; and at other spots these deposits are so large that their thickness in depth is as yet unknown.

The only other description of ore of importance to the ironmaster, which has not yet been mentioned, is the brown hæmatite (hydrated ferric oxide, Fe_2O_3, + a variable quantity of water). This is very widely distributed, extending into the more recent strata, and is of considerable commercial value. It is generally more earthy in its character than the red, and produces a brown streak; this is often used as a pigment, under the name of ochre. The Forest of Dean supplies very large quantities, and, judging by the remains of ancient workings, it seems to date back, as an iron-producing district, as far as to the Roman occupation. Quite recently these ores have been turned to good account in Lincolnshire, Northamptonshire, and Oxfordshire, where they occur in considerable beds in the Oolite rocks. Increased facilities in bringing coals by rail have mainly contributed to the extension of the iron trade into these regions. The brown hæmatites vary considerably in the amount of metallic produce, being mixed with very variable quantities of earthy matter.

In addition to these there are many other compounds of iron in Nature, such as the common pyrites (sulphide of iron), arsenical pyrites or mispickel, which are not used in iron making, but are of value to the chemical manufacturer for the sulphur and arsenic they respectively contain.

Before commencing to reduce the ores it is important to know precisely their contents, because, in the first place, they may not yield the per-centage of metal which their appearance might lead one to expect; in the second, the nature and quantity of the earthy ingredients should be known, in order to determine the most suitable flux to be used; and, in the third, they may contain, in addition, some other ingredients, such as sulphur and phosphorus, which, even in small quantities, are deleterious. Any fresh deposit of ore is therefore subjected to assay, or analysis, before putting it into the blast-furnace.

The object of the assayer is to produce on a small scale what the smelter would realise on a larger one, from which it is easy to calculate the proportion of metal. The article which is required to be tested is put in the crucibles, which are placed on the fire-bars of the furnace, and packed all round with coke or anthracite broken small; the ash-pit below is open in front

for the admission of air, and the chimney should not be less than thirty feet in height, so as to promote a powerful draught, with a damper for regulating it. The crucible is first brasqued, or lined with finely-pounded charcoal rammed hard, leaving only a small hole in the centre, sufficient to contain 100 grains of ore and the necessary flux. These are both pounded fine, and well mixed together. The flux varies according to the description of ore and the judgment of the assayer. The hæmatites will only need a little borax or flint glass. Ores containing silica, but deficient in lime or alumina, will require the addition of limestone or clay. Those, on the other hand, in which these prevail and the silica is wanting, are mixed with pounded quartz. Some need no flux at all. The charge having thus been put in the crucible, it is covered over with some more powdered charcoal, and then the lid is luted on with fire-clay, the crucible put into the furnace, and the fire got up, gently at first, lest the crucible should crack, but ultimately to a white heat, at which it is maintained for about a quarter of an hour. It is then allowed to cool down, the cover of the furnace is removed, and the crucible taken out. On opening it and removing the brasque, a solid button of iron should be found at the bottom, separate from the slag. If the metal is generally diffused through the mass, and only in a partially melted state, it indicates either that the temperature was insufficient or the flux unsuitable, and the experiment must be repeated. The button of iron is weighed, and that represents the per-centage of metal in the ore. The quality is commonly tested by hammering. If the button is flattened by the blow, the iron is good; but if it flies to pieces, and the fragments show a crystalline texture, it is of inferior quality. The colour and appearance of the slag will also tell the assayer whether he has appropriately selected and proportioned the ingredients of his flux, which is also a matter of much interest to the smelter. In order to save fuel and labour it is usual to have the furnace arranged to hold four crucibles, and so make that number of assays at the same time.

By the ordinary processes of chemical analysis every constituent of the ore can be ascertained quantitatively, and thus the per-centage of metal and the most appropriate fluxes can be easily deduced. As a specimen of the result to be thus attained the following is taken from the Reports of the Geological Survey as the analysis of an ore from Eston, in the Cleveland District:—

Protoxide of iron	39·92	per cent.
Peroxide „	3·60	„
Protoxide of manganese	0·95	„
Alumina	7·86	„
Lime	7·44	„
Magnesia	3·82	„
Potash	0·27	„
Carbonic acid	22·85	„
Silica	8·76	„
Sulphur	0·11	„
Phosphoric acid	1·86	„
Moisture	2·97	„

This will yield 33·62 per cent. of metallic iron.

BRICK AND TILE-MAKING.—II.

BY GILBERT R. REDGRAVE.

TERRA-COTTA, BRICKS AND TILES.

The moulds used for terra-cotta are necessarily what are known as "piece-moulds," that is, they are composed of a series of slabs or pieces which fit together by means of checks or tallies, and form the sides of a sort of hollow box without a lid, the opening in which constitutes the back of the block, or that part which is not to be visible in the finished work. Having carefully fitted together and secured with string or cord the pieces of his mould, which should be as few in number as possible (we will not here describe the making of the mould from the model, as that is simply the work of any moulder or skilled plasterer), the workman rolls out some of the clay by his side into sheets, from one and a half inches to two inches thick, and by means of the open side forcibly introduces one of them into the mould. He then squeezes the clay carefully into all the crevices and depressions, which of course coincide with the projecting portions of the finished block. It needs considerable skill and dexterity to distribute the clay equally over the mould, and to fill out all the inequalities of enriched blocks—to force the clay fairly, in fact, into all the corners and crannies of the mould; and unless the clay is tolerably uniform in thickness throughout the work, all kinds of difficulties arise in the drying.

Having completely filled his mould, the workman, according to his judgment, introduces one or more stays or supports; these are webs of clay put in, in the form of partition walls, to support the main frame-work and to tie together the sides of the block. Some manufacturers then close up the back, leaving only a few small apertures for the exit of the moisture in drying and for the admission of the cement in setting. We think it, however, in all cases advisable to leave the back open, as the drying of the inner and outer surfaces of the clay then goes on more uniformly, and it becomes possible in fixing the terra-cotta to build the brickwork into the terra-cotta. In making a quantity of blocks of one pattern, the manufacturer invariably prepares a number of moulds, as, owing to the time the clay has to remain in the mould, the moulding operation is necessarily a very lengthy one. When a mould has been filled it is placed on a hot flue to dry, where, according to the nature of the clay and the size of the block, it may remain from two to six hours. In this time, owing to the absorption of the plaster and the shrinkage of the clay, in consequence of the loss of its water, the block leaves the sides of the mould, and readily permits of the removal of the several pieces. On quitting the mould the terra-cotta is far from being ready for firing, and requires a vast amount of scraping and trimming before it is set aside to dry; thus the junction of each piece of the mould produces a seam or "comb" on the block, which has to be very carefully removed; then, in spite of the utmost care in pulling away the sides of the mould, small pieces of clay frequently cleave to them and are broken off the block, and some chinks remain unfilled with clay. These places have to be repaired, and little irregularities on the surface have to be smoothed over, and all this patching and polishing throw great temptations in the way of the workman; thus it is that in a carefully modelled piece of terra-cotta it frequently happens that much of the crispness and spirit of the work is sponged and scraped away in this process of cleaning and repairing. After leaving the moulder the block is taken away to the drying loft or chamber, where it may remain for a week or a fortnight, according to the season and the state of the weather; and during this period it should be repeatedly turned, in order to prevent it from settling down in any one particular direction. The drying should not be carried on too rapidly or by means of artificial heat, as this tends to make the clay crack, and once cracked the block is worthless. The workman judges of the sufficiently dry state of the clay by its colour and by the weight of the block.

We may now suppose that a number of blocks have been made and are ready for firing, and we will attempt to give a brief description of the kilns. The kilns or ovens in general use are of three different kinds:—1. Circular in plan, with fire-places all round, varying from eight to twelve, or even sixteen in number. 2. Oblong, with fire-places at the sides and doors at either end; those kilns may have from eight to twenty fire-places or fire-holes. 3. Newcastle kilns, which are oblong in plan, with the fire-places at one end only, usually three in number. Of these kilns the latter are the least economical, that is, they require the most fuel—viz., about one ton of coal to one ton of goods; and the round kind are the best, as they are frequently fired with but little more than half this quantity. For all well and uniformly burnt terra-cotta the interior of the kiln should be "muffled"—*i.e.*, have an inner case or "muffle-lining" of fire-bricks, protecting the goods from direct contact with the flames and coal smoke. In some parts of the country the terra-cotta kilns, and even those in which the white glazed bricks are fired, have no muffle, but a kind of rude protection is built up in coarser goods round the finer articles to be burnt. In some places, too, they use a sort of half-muffle, called a "ring-wall," consisting of a lining reaching about half way up the kiln, which protects the ware from the first violence of the flame, and takes the place of the "bags" in an ordinary biscuit or gloss oven.

To describe adequately the various systems of firing would, we fear, lead us far beyond the limits of the present series of papers. We may state briefly that the two chief methods are respectively known as the up-draught and the down-draught, according to the manner in which the flame is conducted from the furnace through the kiln to the chimney. The ordinary up-draught is the old-fashioned plan; and the down-draught

principle, which, when properly managed, saves a considerable amount of fuel, is of more recent introduction. The whole subject of pottery firing deserves careful study and investigation, as probably in no other manufactories, except in iron-works, does such a reckless waste of fuel take place as in potteries. The fire-places, or fire-holes, as they are very justly called, are rarely, if ever, supplied with fire-bars, and consist of mere rectangular brick chambers, with an orifice at the top for supplying the fuel, and an arched opening to the ash-pit, to get at the fire for the purpose of stirring it and withdrawing the ashes and clinkers. The fire is prevented from falling out of the fire-hole by means of a rough open wall of brickbats, called the "glut-bricks," the arch itself being called the "glut." The goods which are to be fired are introduced into the kiln through an opening on one side or one end of it, and are built up one on the top of the other from the floor to the roof. The floor is covered with a layer of crushed pottery or sand, and in a round kiln the heaviest and most massive objects are placed below, with the lighter or more hollow pieces above them. Great care and experience is, of course, required in filling a kiln and in stacking the goods, for unless the different objects are disposed with reference to the amount of heat they have to undergo, and the amount of weight they can safely bear, the contents of the kiln may be, and very often are, thrown into sad confusion when the heat comes to be applied.

When the kiln is full, and the smoking process is completed, the doorway is built up in bricks laid dry and plastered over with loamy clay, and the cracks and various openings are carefully stopped with the same material. Here and there, however, a brick is so arranged that it may be readily removed from time to time to observe the appearance of the interior of the kiln during the different stages of the firing. For many hours after the fires are lighted it is necessary to keep them very low, in order that the ware may be, as it is termed, "smoked." For this process it is also advisable to keep a current of air passing through the kiln, and therefore it is usual to leave the doorways and other inlets either partially or entirely open until the smoking is completed, and the goods are thoroughly dry. In the earlier part of the process dense volumes of steam are given off, which go to form the so-called "white smoke," and when this evolution has ceased, the fires are gradually made up until they are "brought up to the mouths," as it is called—*i.e.*, till the whole of the fire-chamber is full of fuel. The smoking may take, according to the nature of the contents of the kiln and their condition with respect to dryness when they were put in, from twenty-four to forty-eight hours, after which the "full firing" will take from sixty to ninety hours with thoroughly well-burnt fire-clay.

The treatment of the fires, the method of stoking, the management of the draught in the chimney, and a host of minor details in this stage of the manufacture of terra-cotta, require a vast deal more attention than they at present receive. The firing is, we are bound to confess—as usually practised at the present time—a very haphazard and random proceeding. It is so, even in the Potteries, with the finest kind of porcelain, and much more so with fire-clay goods and common ware. The truth of this matter is that manufacturers do not care to provide shelter round the kilns for the men, and thus, at night-time especially, the firemen are only too glad to avail themselves of any pretext for deserting their work. One mode of obtaining an hour or two's sleep, and of absenting themselves from the kilns, is by what is called "lumping" the fires—that is, filling them up with coal and piling a great heap of larger lumps over the mouth, so that as the fuel gradually burns away the lumps may drop down into the fire-hole. Of course this is a very wasteful and bad practice, as the piles of coal very often burn outside instead of inside the fire-chamber, or the fuel, instead of dropping down when wanted, "hangs in the mouth," and causes the fires to burn hollow.

A hollow fire is about the worst thing possible, as currents of cold or imperfectly heated air are thus allowed to enter the kiln, and may in a very short space of time undo the work of many hours, by cooling down the ware. There can be very little doubt, also, that unsteadiness in the mode of introducing the heat is fatal to the contents of the kiln, as alternate intervals of heating and rapid cooling can scarcely fail to crack the goods.

The firing of the terra-cotta is mostly conducted by means of "trials," in the same way as with fine pottery—that is, the fireman judges of the condition of the contents of the kiln by means of trial-pieces of ware, which he withdraws from time to time with an iron rod, through openings called "trial-holes," specially contrived for the purpose. These trials are of various forms, a very common one being a ring, cut off from the end of a drain-pipe, or a small basket, the aim in all cases being to enable the fireman to get hold of the piece readily. From three to four of these trials are placed at the top and bottom in each part or "quarter" of the kiln, and the workman is supposed, at the end of the process, to produce the trials he has withdrawn at each different period of the firing. These pieces, of course, indicate to him the relative condition of all parts of the kiln, and he can then manage his fires accordingly. Thus, he may have to "push" certain fires and slacken others, in order to "bring up the quarters" all alike, or he may have to "work for the top" or bottom if he finds any important difference in the state of his top and bottom trials. The theory of trials is all very well, but an experienced workman goes more by the look of the goods through the "spy-holes" than by anything else. Moreover, the trials alone do not constitute a reliable guide, especially when the kiln is old and "leaky," or full of vents and cracks. A new kiln will frequently "fire up" in half the time an old one will, and thus show a vast saving in fuel. We should like here to have described some of the new inventions for kilns and furnaces; but this would, we fear, take up more space than we can spare.

After the last stoking the fires are allowed to burn gradually down, and in twenty-four hours' time the door is opened and the cold air permitted to enter the kiln. This should not be done too soon, as it might cause the ware to "fly" or crack. When terra-cotta is wanted in a hurry it is often got out quite hot, and before the kiln is thoroughly cool a new lot of goods has been put in and the fires are again lighted. It will readily be understood that this alternate expansion and contraction are most prejudicial to the stability of the kilns, and it is necessary to build them most solidly and to tie them together with iron hoops or bands. However carefully this is done they soon begin to split open and crack, and the crown of the kiln, which consists, of course, of a brick dome, sooner or later falls in or has to be taken down. The repair of his kilns is consequently one of the most expensive items incurred by the manufacturer.

The colour of fire-clay terra-cotta, when well burned, is, as we have observed, a dark buff, and to our mind terra-cotta can hardly be too much fired. Those blocks which are under-burnt or are too pale in colour to build in properly with the other work may readily be fired again and made to take a deeper tint.

We have thus glanced at the various stages in the manufacture of fire-clay terra-cotta, and we may, in concluding this portion of our subject, make a few remarks on other varieties of this material.

Most manufacturers can, if desired, furnish a red terra-cotta, and many firms will, if necessary, give us a blue or a green colour at a slight extra cost. We cannot but regard the white or buff ware as the only true terra-cotta, in spite of the fact that almost all the ancient ware was red in colour. We have given our reasons for maintaining that the red clays will not stand any great degree of heat, and because in the dry climates of Greece and Italy the red ware has lasted well, we must not assume that it will do so in our own damp climate. We are convinced that there is no more durable material than well-burnt fire-clay, and if a red colour is necessary it should be obtained by mixing colouring matter with the clay. White terra-cotta forms an excellent dressing for a red brick building, and appears to be structurally the true method of decorating it. Terra-cotta and stone-work should never be used together, and red terra-cotta should not be used with a white brick building. Terra-cotta can, if it is required, be made to take a coloured enamel-glaze, and it is then known as "della robbia" ware, or, in a humbler form, as glazed bricks, which are now made in various colours by several manufacturers in the neighbourhood of Leeds. Lastly, terra-cotta is admirably suited for receiving a glaze, technically known as "salt glaze," and clay in this form is well known to us in the shape of the numberless kinds of so-called "sanitary goods." This glaze is produced by throwing on the fires at the end of the "firing up" a few handfuls of salt, which is decomposed on the surface of the hot ware in the kiln, and forms a glaze of silicate of soda with the evolution of hydrochloric acid.

OBJECT DRAWING.—IV.

Fig. 21.—This is a triangular prism, the end of which is parallel to the picture-plane.

The end, which in this instance is an equilateral triangle, is to be drawn first; and from its angles, *a*, *b*, *c*, lines are to be drawn to the point of sight; the line *d e* will then complete the lower side of the prism.

Now it is clear that *d e* is the base of the triangle forming the distant end of the prism; and knowing that this triangle is equilateral, having merely been moved backward from the foreground, but the direction of its plane not having been changed, it would be easy to draw an equilateral triangle on *d e* without any further trouble; but this would not teach the principle of drawing the figure if the triangle were not equilateral; and it is, therefore, desirable to proceed in the method from which such instruction is to be derived.

From *c* draw the perpendicular *c f*, and from *f* draw a line to the point of sight, which will pass through *d e* in *g*. At *g* draw a perpendicular, to correspond with that drawn on *f*. From *c* draw a line to the point of sight, meeting the perpendicular *g* in *h*. From *h* draw *h d* and *h e*, which will complete the view.

Fig. 22 is made up of three models of equal size, and forms a simple doorway at right angles to the plane of the picture.

This is another application of the models used in the previous lesson. Draw, in the first place, the side of the one upright which is parallel to the spectator—viz., *a b c d*. From *b* and *c* draw lines to the point of sight, and erect the perpendicular *f g*. Draw a line from *d* to the point of sight, and from *g* draw a line parallel to *c d*, which will complete the view of this part of the model, rendered as a mere slab. Now draw the perpendiculars *h* and *i*, and from *a* draw a line to the point of sight. From *i* draw a line (*i j*) parallel to *a b*, and at *j* erect a perpendicular. This will give the inner side of the distant upright. Now produce the line *c g* until it projects sufficiently beyond the perpendiculars, bearing in mind that as all lengths are diminished by distance, the length from *g* to *k* must be less than *c* to *l*, although these would be equal in the model. Then draw the rectangle *l m n o*, representing the end of the horizontal block. From *o* draw a line to the point of sight. At *k* draw a perpendicular, which will give *p*, the point at which the distant horizontal is to be drawn. Now from *n* draw a line to the point of sight, cutting the horizontal in *q*, and the object will thus be completed.

Fig. 22.

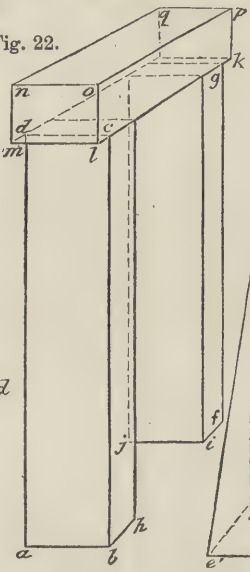


Fig. 21

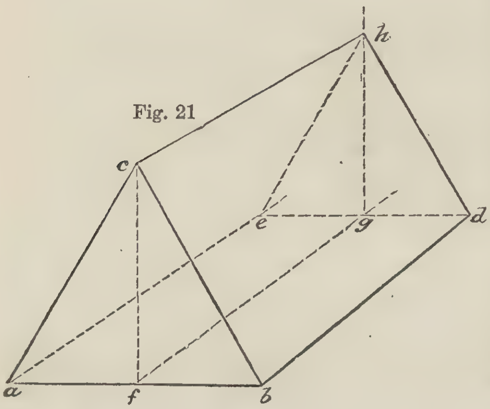


Fig. 23.

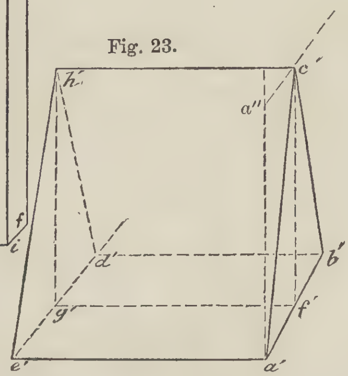


Fig. 23 is another triangular prism.

In commencing this figure, sketch the plan *a′ b′ d′ e′*, remembering that *a′ b′*, which represents the base of the end, being now at right angles to the picture, will converge to the point of sight. Between *a′* and *b′* set off the point *f′*, making *a′ f′* slightly longer than *f′ b′*, and at *f′* erect a perpendicular. Erect another perpendicular at *a′*, and mark on it *a″*, equal to the real height of the triangle. From *a″* draw a line to the point of sight, cutting the perpendicular *f′* in *c′*. Draw *a′ c′* and *c′ b′*, which will complete the triangle.

From *f′* draw the horizontal *f′ g′*. At *g′* erect a perpendicular, and from *c′* draw a horizontal intersecting this perpendicular in *h′*. Draw *h′ e′* and *h′ d′*, which will complete the object.

The group forming Fig. 24 consists of a cube standing on two square slabs which form steps around it, the cube being covered by a pyramid.

Draw the rectangle *a b d c* representing the vertical edge of the lower slab. From *c* and *d* draw lines to the point of sight, and complete the view in the manner with which the student will now have become acquainted.

Now the lower slab forms a step around the second one equal in width to its height; therefore, having drawn diagonals in the upper surface of the slab, set off *c e* and *d f* equal to *a c*, and from *e* and *f* draw lines to the point of sight, cutting the diagonals in *g*, *h* and two distant points, as shown in Fig. 2 (page 4). The quadrilateral formed by joining these points will be the plan of the second slab.

At *g* and *h* erect perpendiculars, which, as the second slab stands a little back from the picture-plane, will be drawn rather shorter than *a c*. Draw a horizontal line for the edge, and complete the object as before.

Set off, on the edge of this slab, the width which it projects beyond the cube, which, as in the previous case, is the same as the height of the slab. Draw lines to the point of sight, cutting the diagonals, and this will give the plan of the cube and pyramid, which may now be completed in the manner shown in the figure.

The object which is shown in Fig. 25 is the one which has already been drawn in another position in Fig. 22. The front elevation is now parallel to the picture. This view is so extremely simple that the student may fairly be expected to draw it without further instructions.

In the previous lessons the objects have been so placed, that their front and back surfaces have been parallel to the picture.

Under such circumstances, the sides alluded to retain their original *shape*, however much they may be diminished in *size* by being moved into the distance.

This has been exemplified in page 132, in which the front of the cube in Fig. 13 is a square like that of Fig. 11, but reduced in size, in consequence of its being placed back in the picture; and similarly, the side of the distant upright in Fig. 22 is similar in shape to the side *a b*, but is diminished for the same reason.

It now becomes necessary to consider the method of drawing objects when their sides are placed at different angles to the picture-plane.

In order that the student may fully comprehend the exact difference between the positions of the objects now to be considered, his attention is called to Figs. 26 and 27 in the following pages.

Fig. 26 is the plan of a cube, placed so that its front and back

are parallel to the picture, which is supposed to stand on the line A B. This position has already been explained in reference to Fig. 1 (page 4), and several such subjects have been subsequently worked out.

Fig. 27 shows the plan of the same object when placed so that neither side is parallel to the picture-plane, A B; only the angle a is really in the foreground, the other surfaces receding from it. In the present plan it will be seen that the object is placed at equal angles—that is, the side standing on $a\ b$ recedes at the same angle as does the side standing on $a\ c$, and it will be seen from the plan that the side $c\ d$ is parallel to $a\ b$, and $b\ d$ to $a\ c$.

We will now proceed to draw the cube so placed.

Let $a\ e$ (Fig. 28), be the vertical edge of the cube which is

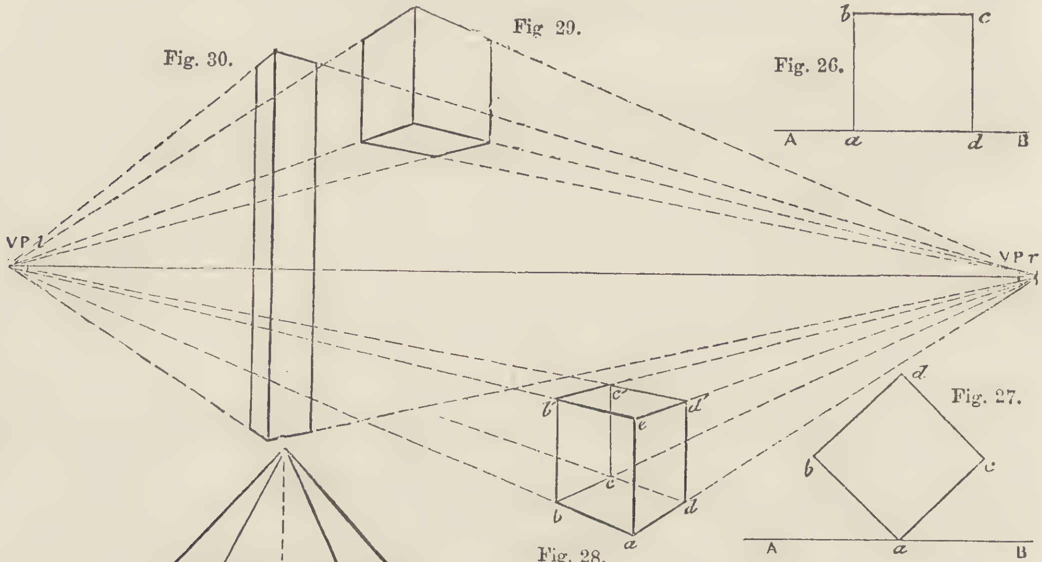


Fig. 30.

Fig. 29.

Fig. 28.

Fig. 26.

Fig. 27.

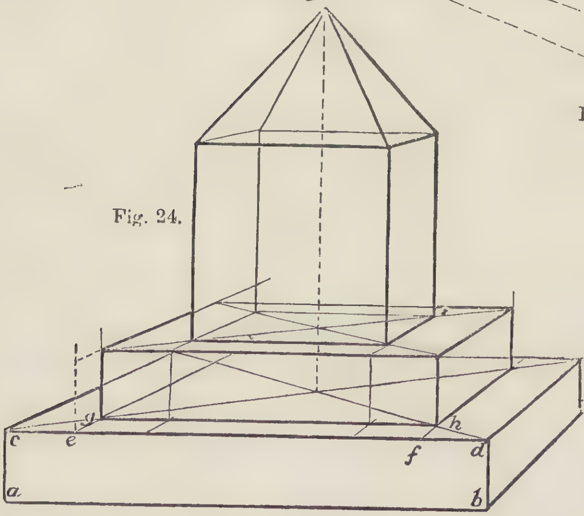


Fig. 24.

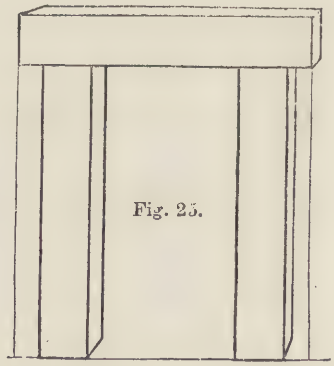


Fig. 25.

nearest to the spectator, and resting on the point a in the plan. Now we know that the edge $a\ d$ in the plan and the corresponding edge of the top of the cube are *horizontal;* but we have seen that horizontal lines when not parallel to the picture converge to a point in the distance—that point being the point of sight when the lines in the object are at right angles to the picture; but the line $a\ d$ and the corresponding edge of the upper surface, $e\ d'$, are, as has been shown by the plan, *not* at right *angles* to the picture, and therefore they converge (*not* to the point of sight, but) to a point in the horizontal line called the vanishing-point. The lines $a\ b$ and $e\ b'$ converge in a similar manner to a point on the left side.

Care must be taken that these lines are not drawn up too obliquely, which makes the sketch appear as if the object were tilted up from the back. It must be understood that the vanishing-points need not necessarily be on the paper, nor need the lines be drawn entirely to them. A little observation and practice will enable the student to judge of the amount of inclination required, and to sketch the object with tolerable correctness. The rules for finding the exact position of the vanishing-points, etc., do not fall within the province of these lessons, but are fully treated of and practically worked out in the lessons in "Practical Perspective."

The student must use his judgment, too, in determining the positions of the perpendiculars $b\ b'$ and $d\ d'$, bearing in mind that the width of the sides will vary according as the object is moved to the right or left, and that both sides will be the same when the object is placed immediately opposite the eye.

The following principle will now be found useful to the student:—

All lines which in the object are parallel to each other, vanish in the same point.

Now it has already been shown in the plan that $b\ d$ is parallel to $a\ c$, and that $c\ d$ is parallel to $a\ b$.

Therefore, according to the above principle, draw a line from e to the right-hand vanishing-point VP^r, to which $a\ d$ and $b\ c$ have already been drawn; and from e draw a line to VP^l, to which the lines $a\ b$ and $d\ c$ converge. The object being drawn as if transparent, it will be seen that the same rule is carried out in relation to the distant lines of the base of the cube.

Fig. 29 is a view of the same cube when placed above the level of the eye of the spectator, and the lines therefore run *down* to the vanishing-points on the horizontal line.

Fig. 30 is an upright block which, being higher than the spectator, passes above the horizontal line; and thus, although the lines from the nearest angle at the bottom are drawn upward, those from the top incline downwards.

OPTICAL INSTRUMENTS.—IX.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLE-FRAMES (*continued*).

I SHALL now proceed to describe and figure the various forms of spectacle-frames; but before entering on a detailed description of these, I may remind the reader that at page 112 of Vol. I. of THE TECHNICAL EDUCATOR I have described and figured (Figs. 4, 5) two forms of "protectors" used for shielding the eyes from dust or glare of light, about which it will be unnecessary to say anything further here.

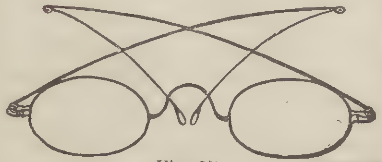


Fig. 27.

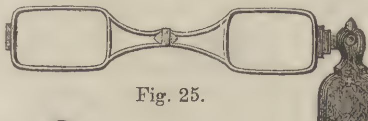


Fig. 25.

Fig. 22.

Hand Reading-glasses are large convex lenses, of various sizes, mounted in circular metal frames, fitted to ebony or ivory handles. These glasses are sometimes cut into an oblong shape to reduce their weight. Such glasses are often used when the sight begins to dim, for reading small print by lamp-light. Even with glasses of large diameter, it will be noticed, as a rule, only one eye is employed; but as persons usually read with the greatest comfort when the glass is held at such a distance from eye and object that the rays proceed in a parallel direction, not much mischief accrues. Nevertheless, their proper office is for magnifying small objects of art, natural history, etc.

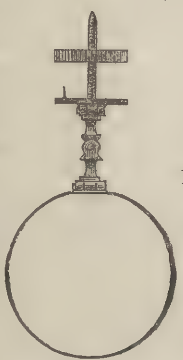


Fig. 20.

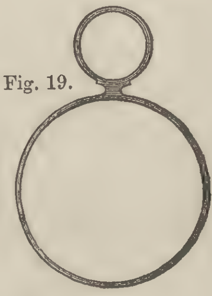


Fig. 19.

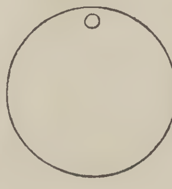


Fig. 17.

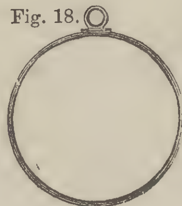


Fig. 18.

Eye-glasses are single lenses, which may be simply drilled, as in Fig. 17, or mounted in light rims of horn, tortoiseshell, steel, gold, or plated metal, as in Figs. 18, 19, to suit the taste or pocket of the purchaser, and are suspended from the neck by a plaited silken cord, or they may be fitted with a universal joint, on a stem that can be screwed and clamped on to the front of a hat, as shown in Fig. 20, to meet the requirements of shooting and riding. The occasional use of single glasses on distant objects can do no harm to the eye; but their constant use on near objects tends to alter the focus of the eye thus armed with extra power (which eye is usually the one on the right side); while, moreover, the other eye tends to deteriorate from want of use, and may become amblyopic. When the necessity for optical assistance is really felt, it is preferable at once to adopt double eye-glasses or spectacles.

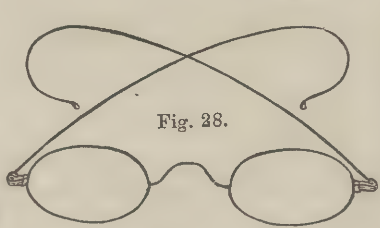


Fig. 28.

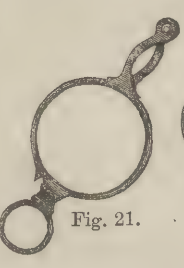


Fig. 21.

Fig. 23.

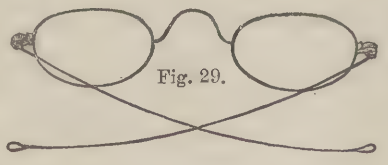


Fig. 29.

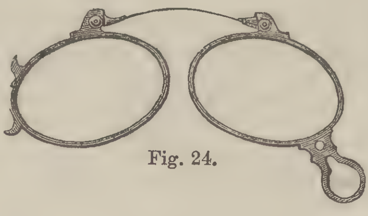


Fig. 24.

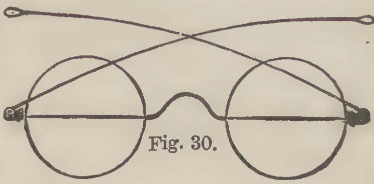


Fig. 30.

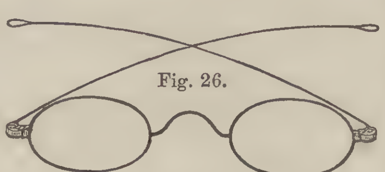


Fig. 26.

Dr. W. C. Wells, in his work on "Vision," quotes the experience of the late eminent optician, George Adams:—"The fact is this, that he does not know a *short-sighted person* who has had occasion to increase the depth of his glasses if he began to use them in the form of *spectacles;* whereas he can recollect several instances where those have been obliged to change their *concave* glasses repeatedly for others of higher powers who had been accustomed to apply them to *one eye only.*"

Usually it is myopics (*and pretended myopics*) who take to single eye-glasses. Every-day experience teaches us that objects appear considerably clearer and brighter when seen with both eyes than they do when seen with one only.

Hand-folders are glasses so mounted in horn, tortoiseshell, or metal frames that they close over each other, as shown in Figs. 21, 22, 23, 24, and so occupy less space than spectacles, and are very conveniently carried in a waistcoat pocket.

The French term these *pinces nez,* as they pinch the nose either by the folding joint, as shown in Fig. 22, or by the action of a steel spring that unites the lenses by hinge-joints, as shown in Fig. 24.

An elegant form of the double eye-glass, especially suited for ladies, is the *lorgnon* (Fig. 25), usually, but erroneously, called a *lorgnette,* which term the French apply to an opera-glass, whether it be large or small.

The objection to all such frames is that it is mere haphazard whether the lenses are centered with the axes of the eyes of the wearer, or are held parallel to the eyes, so that the strain and irritation that may be set up in the organ of vision counterbalance the advantages derived from their apparent convenient form.

Spectacle Frames.—The usual form of oval-fronted frames with single sides is shown in Fig. 26, and the "turn-pin frames," with double sides working on a pivot, in Fig. 27.

Invisible Flexible Frames are made with very light wire sides, curved to fit behind the ears, and the fronts, instead of being made with rims into which the lenses fit, are buried in grooves cut in the flat edges of the glasses. This form (shown in Fig. 28) is much affected by clergymen, and is one well suited for the short-sighted when walking or riding.

Pantoscopic Frames are made with the rims flattened at the tops, as shown in Fig. 29, and set obliquely to the eye, so as to be in the best position for the long-sighted to look upon near work, while it enables them to gaze upon distant objects unobstructedly.

Divided Spectacles are made with "round-eye fronts," and two lenses of different focus are neatly cut across their centres, and then carefully adjusted in their frames, so that the halves of long focal length are in the upper, and the halves of shorter focal length in the lower segment. Such glasses have been found very useful to artists who have to look rapidly from the distant object to the near canvas on which they are depicting it. Both Sir Joshua Reynolds and Benjamin West employed such spectacles, which are certainly preferable to the clumsy and heavy arrangement where two pairs of glasses were made to turn in combination or separate, by means of a hinged joint. The divided spectacle is shown in Fig. 30. Benjamin West for many years wore such an arrangement, with the upper halves of 30 inches and the lower of 12 inches focus; but some years before his death, which was at the age of ninety, the lower halves were changed to a focus of 8 inches. His glasses were $1\frac{1}{2}$ inches in diameter. The philosopher Franklin was slightly myopic, and had little power of accommodation, and for looking at a distance he had need of negative, for seeing near objects he had need of positive glasses. He therefore devised a pair of divided spectacles, and combined the two halves so that the concave occupied the upper and the convex the lower portion of the frame, and thus provided very well for his want of accommodative power. Such spectacles have been called "Franklin's glasses." Of late years the French have combined in one lens, what Franklin attained by cutting and combining two lenses, by grinding the upper and lower halves of different foci, so that, according to an oculist's order, opticians can supply lenses of different positive or negative focus in the two halves, or positive focus above and negative below of any given foci. Such lenses are termed "*verres à double foyer*."

It is indispensable that these should be accurately adjusted at the proper height before the eyes, so that in looking at a distance the rays may fall upon the upper, and in looking at near objects through the lower part of the organ of vision. The pupils must not be opposite the line that intersects the upper and lower lens, or confusion of vision will result. The proper set of the frames, in ascertaining this point, must be determined more by moving the eyes than by moving the head.

While speaking of spectacles used for near and distant objects, I may note the necessity for checking the foolish practice of some long-sighted people, who, while wearing convex glasses suited for viewing near objects, also employ them for viewing distant objects. As such improper use of spectacles will bring about loss of the accommodative power of the eyes, they should remove them when looking at distant objects, or adopt the pantoscopic form. When speaking of spectacles for eyes of different foci, at page 355, I gave the practice of Donders, also followed by many other oculists, which is founded on the belief that if in such cases we supply lenses of different foci to suit each eye, though we make the range of accommodation for each eye more equal, *the magnitude* of the images in each would be unequal, and the result unsatisfactory.

It is curious that so great an authority on the optics of the eye should have arrived at such a conclusion, for it has been experimentally demonstrated by Mr. Charles Heisch, of the Middlesex Hospital, by an instrument specially constructed for the purpose, that if a patient, *having eyes of different foci*, be accurately fitted with glasses of *different foci*, exactly suited for each eye, then the two images may be made of *equal magnitude*, but the converse will result if glasses of *equal foci* be employed for each eye.

When the difference is slight this method of treatment may be disregarded, if accommodation be good; but even with such a difference, say, of a focus of 14 inches for one eye and 12 inches for the other, much good results from suiting both eyes properly, according to the dictates of optical laws.

Spectacle glasses must be kept clean and bright, and should be wiped with the softest and cleanest of wash-leather, or fine soft tissue paper. When not in use the frames should be kept in well-shaped spectacle-cases, to guard as much as possible against the lenses being scratched. Should they be thus injured or otherwise dimmed they should be changed immediately. When reading or working by night the light should fall on the object, while the eyes are shaded, and a glaring, flickering, or unsteady flame should be carefully avoided.

In concluding this long series of articles on the human eye and the optical treatment of its defects, I have endeavoured to give a careful digest of modern practice, especially of that followed by German oculists, to whom we are indebted for many methodical investigations.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XIV.—HENRY BELL.

BY JAMES GRANT.

"INVENTIONS born before their time," said the late Emperor Napoleon III., "must necessarily remain useless until the level of the common intellect rises to comprehend them." The truth of this maxim is well illustrated by the failures of those who in past times have thought of steam locomotion as possible by land and sea: such as when Senor Blasco de Garay made his attempt in the time of Charles V.; when Denis Papin made a similar essay at Cassel, in 1707; and when the unfortunate James Taylor, of whom a memoir was given in THE TECHNICAL EDUCATOR (Vol. I., p. 147), first sought to apply this novel power to inland navigation on Dalswinton Loch and the Forth and Clyde Canal, towards the close of the last century.

Henry Bell, who had inspected the vessel constructed by the latter, as she lay rotting and forgotten at Carron, and who foresaw the vast uses to which such a ship could be applied, and was eventually the first successful adapter of steam to the purposes of navigation in Europe, was born on the 7th of April, 1767, in the little straggling village of Torphichen, in a wooded and sequestered part of Linlithgowshire. The central feature of the hamlet is the ruin of the fortified church of the Scottish Knights of St. John. He was sprung from a race of sober, hardy, and industrious mechanics, being the fifth son of Patrick Bell and his wife Margaret Easton, whose ancestors, for many generations, had been well known in West Lothian as ingenious millwrights and builders; and some of whom had constructed harbours and bridges not only in Scotland, but in other parts of the United Kingdom. As usual with the children of the humbler classes in Scotland, Henry Bell received a plain education at the parish school, and in 1780 was apprenticed to a stonemason.

This employment he would seem to have disliked; and three years after he commenced a new apprenticeship with his uncle, as a millwright, in the vicinity of Torphichen. In 1787, his term being complete, he went to Borrowstownness, on the Forth, to learn the art of ship-modelling, and engaged himself as a journeyman with Mr. James Inglis, engineer, at Bell's Hill, with a view to completing his knowledge in mechanics. After a time he went to London, where he found employment under the eminent Mr. Rennie, whose line of business afforded Bell ample opportunities of acquiring a great practical knowledge in the higher branches of engineering; but being of a restless nature, like many other men of genius, he returned soon again to Scotland, and worked for many years at Glasgow industriously as a simple house-carpenter, and in 1797 was enrolled as a member of the corporation of wrights in that city.

Bell was not without ambition, and it was his greatest desire to contract for some of the public works in Glasgow; but being totally without capital or wealthy friends, he never succeeded in having his hopes realised in that way. "His mind was a chaos of extraordinary projects," says a writer, who seems to hint that he lacked the power of concentration; "the most of these, from his want of scientific calculation, he never could carry into practice. Owing to an imperfection in even his mechanical skill, he scarcely ever made one part of a model to suit the rest, so that many designs, after a great deal of pains and expense, were successively abandoned."

The idea of propelling vessels by steam, on Taylor's principle, was undoubtedly one that took very early possession of his mind.

"In 1800," he writes (twelve years after Taylor's little steamer paddled across Dalswinton Loch), "I applied to Lord Melville, on purpose to show his lordship and the other members of the Admiralty the practicability and great utility of applying

steam to the propulsion of vessels against winds and tides, and every obstruction on rivers and seas, where there was depth of water. After duly thinking over the plan, the lords of that great establishment were of opinion that it would be of *no value* in promoting transmarine navigation."

It is gratifying to think that the hero of the Nile and Trafalgar thought otherwise.

"My lords," said he, emphatically, when Bell brought forward his project again in 1803, "if you do not adopt Mr. Bell's scheme other nations will, and in the end vex every vein of this empire. *It will succeed*, and you should encourage Mr. Bell."

Events have shown how truly the great admiral spoke; and he might have proved a firm friend and patron of the humble projector, but two years later saw him lying dead in the cabin of the *Victory*.

Still constructing models and struggling with circumstances, Bell, who had married, removed from Glasgow, in 1808, to Helensburgh, a watering-place on the Clyde, begun about thirty years before by Sir James Colquhoun, Bart., of Luss. There his wife undertook the superintendence of the public baths, and at the same time kept the principal hotel; while "he continued to prosecute his favourite scheme, without much regard to the ordinary affairs of the world."

Nelson's prophecy speedily became true, when in 1807, on the 3rd of October, Mr. Fulton, who had also inspected Taylor's steamer at Carron, launched the first river-steamer in America on the waters of the Hudson, and regularly corresponded with Bell concerning its progress and development.

In 1811 the latter began to construct a vessel of 30 tons burden, 40 feet long, 10 feet 6 inches beam, with an engine of 3 horse-power, and on a plan that was entirely his own. This craft he named the *Comet*, that year having been remarkable for the appearance of a brilliant one. She was built by Messrs. John Wood and Co., and made her trial trip on the 18th of January, 1812, when she sailed triumphantly from Glasgow down the Clyde to Greenock making five miles an hour against a head wind.

By the midsummer of that year Bell advertised that his wonderful new ship would ply upon the Clyde thrice weekly from Glasgow, sailing "by the powers of air, wind, and steam;" and September saw the voyages extending to Oban and to Fort William, at the mouth of Loch Eil, four days being the time required for going and returning.

Bell had constructed the steam-engine with his own hands; he had encountered, like poor Taylor, those innumerable and indescribable difficulties incident to the career of the unfriended inventor. His success was now, however, complete; and though many others were now encouraged to embark their capital in similar undertakings of a much greater nature, Bell did not realise personally any solid advantages from his discovery. He had, however, the satisfaction, accorded to few, of living to see his invention universally adopted over all the waters of the globe. The Clyde, which first enjoyed the advantages of steam-navigation in Britain, became the great seat for building ships of that kind, and in that respect still maintains its equality with any other port in the world.

"Clyde-built ships, with Glasgow engines," says Dr. Chambers, "make the voyage between Liverpool and New York in ten days. Steamboat building and marine-engine making received their first powerful impulse from the solution of the problem of ocean steam navigation. From tables constructed by Dr. Strong, from returns furnished to him by the various shipbuilders and engineers in Glasgow, Dumbarton, Greenock, and Port Glasgow, it appears that during seven years, from 1846 to 1852, there were constructed at Glasgow and in its neighbourhood, 123 vessels, of which 1 was of wood, 122 of iron, 80 paddle, and 43 screw; consisting of 200 wooden tonnage, 70,441 iron tonnage, 6,610 horse-power engines for wooden hulls, 22,539 horse-power engines for iron hulls, and 4,720 horse-power engines for vessels not being built on the Clyde. During the same period there were constructed in Dumbarton 58 vessels, all of iron, 20 being for paddles, and 38 for screws, and having a tonnage of 29,761; and during the last three years of the same period, 3,615 horse-power engines were made there for iron hulls, and 200 horse-power engines for vessels not built on the Clyde. During the same period, from 1846 to 1852, there were constructed at Greenock and Port Glasgow 66 steam-vessels, of which 13 were of wood and 53 of iron; 41 paddle and 25 screw, consisting of 18,131 wood tonnage and 29,071 iron tonnage; 129 horse-power engines for wooden hulls, 5,439 horse-power engines for iron hulls, and 4,514 horse-power engines for vessels not built on the Clyde. For the whole ports on the Clyde alone, the steam-vessels built and the marine engines made between 1846 and 1852 were as follow:—Wood hulls, 14; iron hulls, 233; in all, 247—of these 114 were paddles and 106 screws. The tonnage of the wooden steamers amounts to 18,331; of the iron 129,273. The engine horse-power in wood hulls was 6,739; in iron hulls it was 31,593: while there was of engine horse-power for vessels not constructed on the Clyde, 9,434; making a grand total of 247 steamers, amounting to 147,604 tons, and of engines, 47,766 horse-power."

Since 1852 the increase has been correspondingly great; and as a sample of the number and tonnage of vessels ordered from private firms, the following may be noted in 1868 alone:—Messrs. Napier, four iron-clads (10,636 tons, and 2,140 horse-power); Messrs. Caird and Co., six steamers, each of 3,000 tons and 600 horse-power; Messrs. Denny, two composite gun-boats, one armour-clad, and five screw-steamers (10,520 tons, and 1,970 horse-power); Messrs. Randolph and Co., eight screw-steamers, two iron ships, and two lighters (10,510 tons, and 1,310 horse-power); Messrs. Thomson, three screw-steamers, one paddle, and one gunboat for Government, and one iron ship (7,000 tons, and 1,020 horse-power).

It was in 1813 that a steamer was first placed on the Thames; but the projector, an Irishman, had to succumb to the privileges of the Thames watermen.

But to return to the subject of our memoir. Notwithstanding that Glasgow owed so much of her greatness to his success, he reaped but little more than honour, and was permitted to approach the confines of old age in very straitened circumstances. The engine of the *Comet*, which was made by Bell's order, and at which Mr. David Napier worked as an engineer, making the boiler chiefly, after lying in the sea for many years after the *Comet* was wrecked in one of the dangerous channels of the West Highlands, was brought to Glasgow, and in 1840 was exhibited as a kind of curiosity to the members of the British Association. Each wheel had four paddles, of the malt-shovel form.

Touched by the unrewarded years of Bell, the late Dr. Cleland, an eminent statistical writer, with a few other benevolent individuals, commenced a subscription in his behalf, and induced the River Clyde Trustees to grant him an annuity of £100, which was continued to his widow; and this was deemed but a humble acknowledgment of the value of his great invention on the part of those guardians of a river whose annual revenue was increased mainly by the impulse given to its trade by steam navigation from £6,676 in 1810 to £76,000 in 1852.

Henry Bell died in his sixty-third year, at the Baths in Helensburgh, on the 14th of March, 1830, and was buried in the parish churchyard of Row, in Dumbartonshire.

On the picturesque rock of Dunglass, in the Clyde, and rising above the ivied ruins of the old castle of that name, towers a great square obelisk to the memory of Henry Bell. It is a conspicuous object to all vessels traversing the river; but no stone marks the resting-place of him who first conceived that project which Bell achieved—Taylor, who launched the first little steamer on the Loch of Dalswinton. Her engine—"the parent engine of steam navigation"—is now preserved in the Commissioners of Patents' Museum at South Kensington.

In concluding this notice of Henry Bell, it ought to be remembered that some sixty years before the time when he sought the patronage of the great Lord Nelson, the idea of propelling vessels by steam had occurred to an Englishman named Hulls. This idea he gave to the world in a small pamphlet, entitled "A Description of a Newly-invented Machine for Carrying Vessels or Ships out of or into any Harbour, Port, or River, against Wind and Tide, or in Calm; for which His Majesty has granted Letters Patent, for the sole benefit of the Author, for the space of Fourteen Years. By Jonathan Hulls. London: Printed for the Author, 1737. Price Sixpence."

To this publication is prefixed a diagram, showing a large, decked vessel, without masts or rigging of any kind, a short funnel, without stays, smoking amidships; three fly-wheels working on deck, but half sunk through it, and two other fly-wheels, with bands over them, working astern; between the

latter revolves a screw, having six spokes, with square shovel ends or paddles, and she tows a two-decker man-of-war. A copy of this publication is preserved in the British Museum, and has been referred to in Robert Stuart's "Anecdotes of the Steam-engine;" but until the days of Taylor and Bell the idea of a steam-vessel went completely to sleep, for it is inseparable from the course of events that every one who has rendered a great service to mankind by any new invention, the objects of which are misconceived or misunderstood, has had to complain of the neglect of his own generation and time. The real recompense in such circumstances is the consciousness of doing one's duty. Even Fulton, the introducer of the steamboat in American waters, had the mortification, at first, of being treated as an idle projector, whose schemes would be ruinous to himself and useless to the world. He was treated as a visionary, and "the new water-vehicle" was ever an object of ridicule till launched. "Their language," he says, "was uniformly that of a sneer or scorn. The loud laugh often arose at my expense; the dry jest; the miscalculation of losses and expenditure; the dull but endless repetition of the 'Fulton folly.' Never did a single encouraging remark, a bright hope, or a warm wish cross my path!" But Fulton, like Henry Bell, was fated to rise superior to the disappointments which usually beset the authors of great and important inventions.

PRACTICAL PERSPECTIVE.—XII.

We now continue the subject that was commenced in the last lesson, repeating the entire illustration to save students the trouble of reference.

Fig. 58 is a view of the same prism when the triangular end is at right angles, and consequently the edges of the prism are parallel to the plane of the picture.

Having fixed the position of the point A, draw a line from A to the centre of the picture.

From A set off A B, equal to the base of the triangle, and from B draw a line to the point of distance, cutting the line A C in B′.

A B′ will represent the perspective appearance of the base of the triangle.

From A or B mark off F, the middle point between A and B, and from F draw a line to the point of distance, cutting the line A B′ in F′.

At F′ erect a perpendicular.

Now it will be clear that the apex of the triangle will be situated upon this line, and the next step must be to determine its exact position.

At A erect a perpendicular, and mark on it the real altitude of the triangle (whether equilateral or otherwise) A C′.

From C′ draw a line to the centre of the picture, cutting the perpendicular F′ in C″; which point will be the apex required.

Join A C″ and B′ C″, which will complete the perspective view of the end of the prism at right angles to the plane of the picture.

We now proceed to project the prism itself, the length of which is parallel to the plane of the picture.

From A set off A D, the real length of the prism, and from D draw a line to the centre of the picture.

From B′ draw a line parallel to A D, cutting the line drawn from D to the centre of the picture in the point E.

A D E B′ will then be the perspective view of the plan of the prism in this position.

From F′ draw a horizontal line, cutting D E in G, and at G erect a perpendicular.

From C″ draw a horizontal, cutting the perpendicular in H.

Draw D H and E H, which will complete the figure.

Let us next consider the object when standing on its triangular end, in which position, of course, all the edges of the prism will be vertical (Fig. 59).

We will in this elementary study suppose the object to stand at equal angles—that is, in such a manner that the sides facing the spectator recede equally from the picture-plane, in which case the third side, A B′ E D, which in both the previous figures formed the plan, will be upright, and parallel to the plane of the picture.

Now the student who has followed the lessons thus far will know that for the projection of objects in angular perspective it is necessary, in the first case, to find the station-point, the vanishing and measuring points, and he will, no doubt, remember that the distance of the station-point from the centre of the picture is equal to that of the points of distance, and therefore, a perpendicular having been drawn at C, the distance C PD set off upon it from C will give S, the point of station.

At S draw a horizontal line, and construct the angles at which the sides of the object recede from the picture. In the present case it will be clear that as the sides of the object itself are at 60° to each other, and as the prism is to be placed at equal angles, there will be three angles of 60° each meeting at S.

Produce the sides of the middle angle of these three until they meet the horizontal line, and thus give the vanishing-points.

It will be remembered that, to find the measuring-points, the length from the vanishing-points to the station-point is set off on the horizontal line, and when this is done in the present instance it will be seen that the measuring-points become coincident with the vanishing-points, since the figure contained by the two vanishing-points and the station-point is an equilateral triangle. It will, of course, be understood that this could only occur when the object is placed at equal angles.

Having, then, found the necessary points, and having fixed the position of the nearest angle of the object at C′, draw lines from this point to the vanishing-points.

From C′ set off on the picture-line C′ A and C′ B, equal to the real side of the equilateral triangle; and from A and B draw lines to the measuring-points, cutting the lines drawn from C′ to the vanishing-points in A′ and B′.

Join A′ B′ by a line which, if the work be correctly done thus far, will be horizontal; but this would not be the case if the object did not stand at equal angles. At C′ draw C′ H, equal to the real length of the prism (A D in the two previous figures); from H draw lines to the vanishing-points; and from A′ and B′ draw perpendiculars, cutting these in D and E.

Join D E, which will complete the projection; and it will be seen that, as required, the distant side A′ B′ E D will be parallel to the plane of the picture.

Exercise 46.

The scale is ½ inch to the foot; height of spectator, 6 feet; distance, 18 feet. The subject is a prism, the end of which is an equilateral triangle of 4 feet side, and the length of which is 8 feet. The same dimensions and object are used in Exercises 47 and 48.

Put into perspective the prism when lying with its end parallel to the picture-plane, and at 6 feet within the picture, and 5 feet on the left of the spectator.

Exercise 47.

Put into perspective the same prism when lying at 9 feet within the picture, its edges being parallel to the picture-plane, and its triangular end being 5 feet on the right of the spectator

Exercise 48.

Put into perspective the same prism when standing on one of its triangular ends, one of its long edges being at 2 feet on the right of the spectator, and the side of the prism on the right of that edge receding at 50° from the picture.

Exercise 49.

Give the perspective view of the object when standing at the same angles as that of the last exercise, but its nearest edge to be at 5 feet on the left of the spectator, and 8 feet within the picture.

Exercise 50.

Put into perspective the same prism when lying on one of its sides, so that its triangular end is vertical, and recedes from the picture at 40°, the nearest angle being at 4 feet on the left of the spectator, and 8 feet within the picture.

In the next study the scale we have adopted is ¼ inch to the foot, the height of the spectator being 5 feet, and the distance 16 feet.

The subject of the study is a pyramid, the base of which is an equilateral triangle of 4 feet side, and the height of which is 4 feet.

In Fig. 60 A B C′ is the plan of this pyramid, from which it will be seen that it is placed at angles of 50° and 70° to the picture-plane.

Therefore at the station-point construct angles of 50° and 70°, and obtain the vanishing and measuring points in the usual manner. It will be observed that neither the station-point, the first measuring-point, nor the points of distance, are shown in this diagram.

In commencing Fig. 61, mark off the position of the point A at 2 feet on the right of the spectator, and draw lines from A to the vanishing-points.

From A set off B and C′, equal to the length of the sides A B and A C′ in the plan. From these points draw lines to the measuring-points, cutting the lines drawn to the vanishing-points in B′ and C′. Join B′ and C′, and the triangle thus formed will be the general outline of the plan.

From E draw a line to VP3, cutting the perpendicular D in F. Then F is the apex of the pyramid.

Draw A F, B′ F, and C′ F, and the projection will be completed.

We now proceed (Fig. 62) to put this object into perspective when placed 3 feet back in the picture.

Let A be the point at which the angle of the pyramid would be situated if it were in the foreground.

From A draw a line to the centre of the picture; from A set

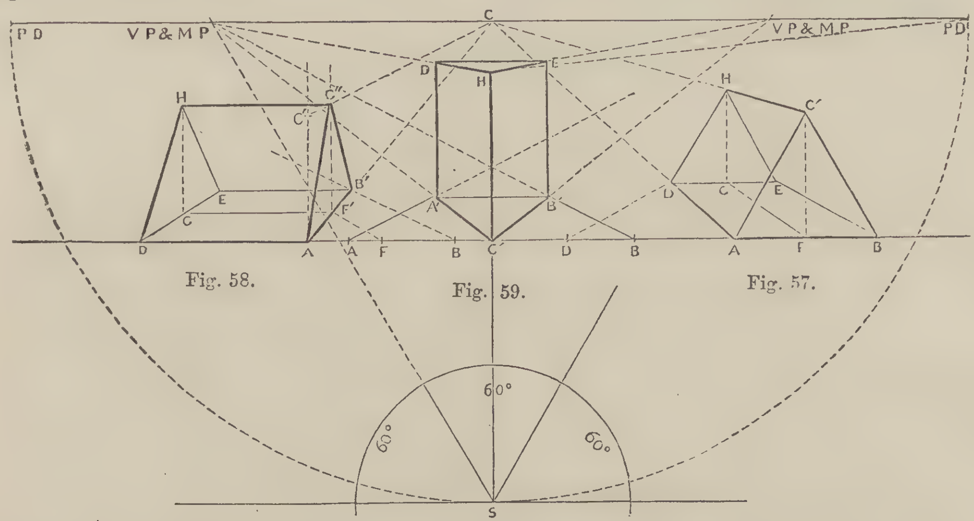


Fig. 58. Fig. 59. Fig. 57.

It is now necessary to find the centre of this figure, and to do this we must return to the plan (Fig. 60).

Draw lines bisecting the angles of the triangle A B C′. These will form plans of the edges of the pyramid, and meeting in the centre, give the plan of the apex.

Produce these lines until they meet the sides of the triangle in the points a, b, and c.

Set off these points between A B′ and A C′ (Fig. 61) on the

off A X, representing the real distance which the object is to be placed backward.

From X draw a line to the point of distance (not shown in the plate), cutting A C in A′, which will be the required position of the point; and through A′ draw the movable base-line.

Now from A set off A B and A C′, equal to the length of the sides; also, between them, the points a and b.

From B and C′ and from a and b draw lines to the centre of

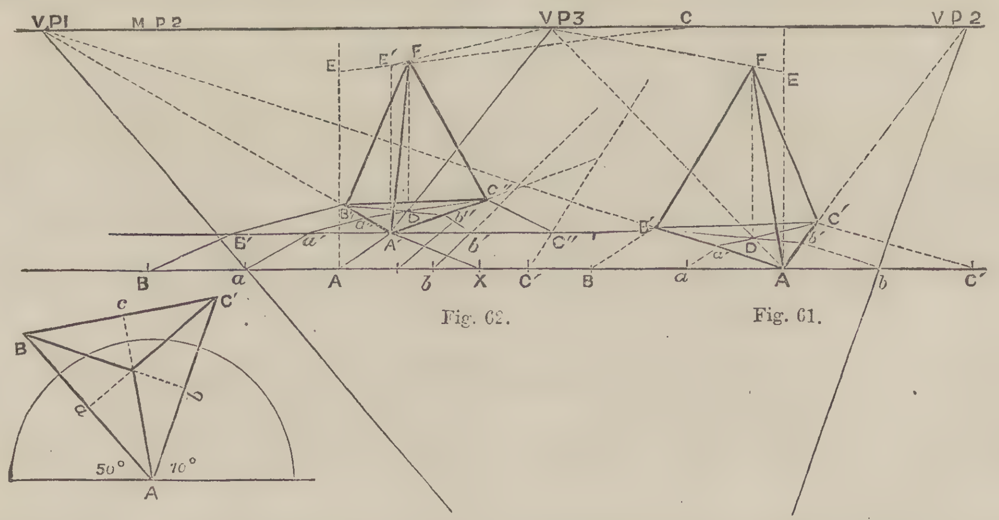


Fig. 60. Fig. 62. Fig. 61.

picture-line—viz., a and b; and from them draw lines to the vanishing-points, cutting A B′ and A C′ in a' and b'.

From a' and b' draw lines to the opposite angles of the plan C′ and B′. These intersecting will give D, the centre of the plan.

From A draw a line through D, and produce it to cut the horizontal line in VP3. This would be the vanishing-point for a plane resting on A D.

Now, to find the perspective height, erect a perpendicular at A, and mark on it E, the real height of the pyramid, in this case 4 feet.

At D erect a perpendicular of indefinite height.

the picture, cutting the movable base-line in B′, C″, a', and b'. The working is now precisely similar to that of the last figure, excepting the mode of finding the height; in order, therefore, that this may be made clear, the process will, as far as is required, be repeated.

From A′ draw lines to the vanishing-points, which, as the object stands at the same angles as the last subject, are those already used in Fig. 61.

From B′ and C″ on the movable base-line draw lines to the measuring-points, cutting the lines drawn from A′ to the vanishing-points in B″ and C″. Join these points, thus completing the general outline of the plan.

Next draw lines from a' and b' to the measuring-points, cutting A′ B″ and A′ C″ in a'' and b''.

From a'' and b'' draw lines to the opposite angles of the plan; and these intersecting will give the centre, D.

From A′ draw a line through this centre, meeting the horizontal line in VP3, being the same point to which the corresponding line in Fig. 61 vanishes, because the planes, standing on these lines in both objects, would be parallel to each other, although the one were in the foreground and the other in the distance, so long as the angles they make in the picture-plane are the same.

It now remains to find the height. To do this, erect a perpendicular at A, and mark off on it A E, equal to the real height of the pyramid.

At A′ erect a perpendicular, and from E draw a line to the centre of the picture, cutting this in E′. The height A E is thus removed 3 feet backward in a track at right angles to the plane of the picture.

Now on D, the centre of the plan, erect a perpendicular, and from E′ draw a line to VP3, cutting it in F, which will give the apex of the pyramid.

Draw A′ F, B″F, and C″F, which will complete the figure.

EXERCISE 51.

All the conditions as to scale, height, and distance of the spectator being the same as in the last plate,

Put into perspective a pyramid, the base of which is an equilateral triangle of 5 feet side, the height being 7 feet, when its nearest angle is at 8 feet on the left of the spectator, and when one side of the plan is at 65° to the picture.

EXERCISE 52.

Give the perspective projection of the same object when at a distance (at pleasure) on the right of the spectator, and 8 feet within the picture.

EXERCISE 53.

Scale, ½ inch to the foot. Height of spectator, 5 feet; distance, 15 feet.

Put into perspective a pyramid, the base of which is a *square* of 4 feet side, and the height of which is 7 feet, when one angle is in the immediate foreground, the sides of the plan receding at 50° and 40°.

EXERCISE 54.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 18 feet.

There is a cube of 4 feet side, on which rests a square pyramid, the base of which coincides with the top of the cube, and the height of which is 5 feet.

Put this object into perspective when standing at 6 feet on the right of the spectator, and 8 feet within the picture.

CHEMISTRY APPLIED TO THE ARTS.—XII.

BY GEORGE GLADSTONE, F.C.S.

ALUM.

ALUM, in a chemical sense, has a wider range of meaning than what is intended in this paper, where we shall confine our attention to the alum of commerce. This article consists of a double sulphate of aluminium and potassium, or aluminium and ammonium, combined with 12 atoms of water; and is represented by the formula $KAl,2SO_4,12H_2O$, or $NH_4Al,2SO_4,12H_2O$.

It is used in the arts for a variety of purposes, perhaps the most important of which are in dyeing and calico printing. It acts there as a mordant, and will be found frequently mentioned in the earlier papers of this series, which treat of those two subjects. It has, however, a variety of other uses. The tallow-chandler employs it to harden his tallow when it is too soft. It is used in leather-dressing; and the doctors often prescribe it, on account of its astringent properties. The baker puts it into bread, to prevent the conversion of the starch into dextrine, making the bread dry and white, but at the same time rendering it less nutritious and digestible.

The alum-works in this country are not very numerous, as they can only be carried on successfully upon the very spot where the principal ingredients are found. By far the most important are in the neighbourhood of Whitby and of Glasgow, in both which places good alum-shales occur. It takes at Whitby about 130 tons of shale to produce one ton of alum; so that even the smallest charge for cartage of the rough material would be ruinous to the manufacturer.

The Whitby shales occur in the Lias formation, and are of two varieties. The one contains about 4 per cent. of sulphide of iron, 5 per cent. of carbon, and 19 per cent. of alumina; the other about the same quantity of the latter, with 8 per cent. of each of the other ingredients named. The rest is principally silica: of lime, which is very prejudicial to the alum-maker, there is only 1 to 2 per cent.

The Campsie shales, near Glasgow, belong to the Carboniferous series of rocks, and vary much more in their composition. What is known as the "top rock" contains about 40 per cent. of sulphide of iron, 11 to 12 per cent. of alumina, and 29 per cent. of carbon; the "bottom rock" about 10 per cent., 19 per cent., and 8 per cent. respectively. They do not contain more lime than those of Whitby. These two shales are used together, as the "top rock" contains an excess of sulphur, and the "bottom rock" an excess of alumina; if used separately there would be a very great waste of materials.

The first step in the manufacture is the roasting of the shale. For this purpose a very large open space is required, as immense quantities of material have to be operated upon. The Scotch shales contain so much carbonaceous matter that they might be calcined without the addition of any fuel—pyrites, when exposed to the air and occasionally wetted, having a great tendency to spontaneous combustion—the decomposition of sulphide of iron being attended with much evolution of heat. The heaps are commenced, however, by making a row of little fires, and covering them with some loose stones or bricks in order to form air-passages; upon the fires are heaped up lumps of shale, and as these begin to burn, more is thrown on until the heap forms a long continuous ridge, which, when mantled, is about 150 feet long, 20 broad at the base, and 15 high. The mantling consists of a layer of old material that has already been exhausted, which is put all over it to moderate the combustion, as without this the sulphur would be liable to be volatilised and lost. It also serves to protect the heap from the changeableness of the climate, winds, and rain. During the prevalence of high winds, it is often necessary to increase the covering, in order to prevent too brisk a combustion, which sometimes even causes the sulphide of iron to mix with the earthy substances, and run into a kind of slag, when a loss of produce is the result. The calcination of the shale requires three to twelve months' time, according to the weather, including the cooling down again after the roasting is over; this is effected by increasing the mantling, so as to exclude the air altogether.

At Whitby the heaps are made of a different form. They are there piled to 80 or 100 feet in height. In order to prevent so large a bulk of shale from becoming too hot in the centre, it is mixed with some of the exhausted mine, and carefully watched, that the mantling may be increased whenever necessary.

In wet weather little channels are made round the heaps to carry off the water which may have drained from them, as it generally contains some quantity of sulphate of aluminium which it has dissolved out. To keep up a continuous supply of roasted ore, the material is not all put into one heap, but is divided amongst several, which are commenced in succession, so that some are in different stages of advancement while what is finished is being put through the next process.

During the roasting the sulphide of iron has been decomposed, and the sulphuric acid liberated has entered into combination with the alumina, forming a soluble sulphate which has now to be removed from the earthy ingredients of the calcined shale. This is accomplished by lixiviation with water.

In the immediate neighbourhood of the calcining ground are shallow cisterns of lead or stone, into which the roasted shale is put, and spread out evenly to a depth of eighteen inches. Water is then let in through a series of taps until the shale is quite covered, and is allowed to remain for twelve hours; it is then drawn off into the clarifying cistern, where it is left to settle before passing to the evaporating pans. A fresh supply of water is let in upon the burnt shale as before, which, in its turn, passes into the clarifying cistern and the evaporating pans; a third is then introduced, but by this time the shale is nearly exhausted of its soluble ingredients, and the liquor drawn from this washing is usually too weak to be evaporated down with profit, so it is reserved to wash some fresh material. A number of these lixiviating cisterns, or "steeps," are generally ranged together, so that the weak liquor from one can be made to serve for the first washing in another steep. In the mean-

time the exhausted shale is removed, and a fresh supply is introduced from the calcining heap.

The lye which comes from these washings, after having deposited in the clarifying cistern the earthy particles carried off with the liquid, contains, along with the sulphate of aluminium, a good deal of sulphate of iron, or green vitriol; and also, at Whitby, sulphate of magnesium, or Epsom salts. As both of these articles are of commercial value, the making of copperas, or green vitriol, and of Epsom salts, forms a part of the business of the alum manufacturer. If it is found that there is more sulphate of iron than aluminium, which is not unfrequently the case, it is usual to remove the first; this can be done by crystallising it out, either by simple evaporation, or by adding at the same time some old iron. If less in quantity, the whole is boiled together, with the view of throwing down the alum first. The main object of this process is to get rid of the large excess of water, and thus concentrate the solution. The plan most economical of fuel is found to be that of having very long flat troughs, with a furnace at one end and a tall chimney at the other, the flue passing over the trough, so that the flames from the surface sweep over the surface of the lye in the troughs, raising the temperature of the liquid very rapidly, and carrying away up the chimney all the vapour of water as fast as it is given off from the surface. Troughs built upon this principle, and covered with a roof to prevent loss of heat by radiation, 60 feet in length, 6 wide, and 4 deep, are capable of evaporating nearly 5,000 gallons in 24 hours. In those works where Epsom salts are also made this plan of evaporating cannot be adopted, for in that case the sulphate of magnesium would be liable to crystallise out, and form a crust on the surface of the lye, thus impeding the further progress of the evaporation. There the flue from the surface is made to pass under the evaporating pans, and the heat is communicated through the metal bottom. This plan is not so economical of fuel as the other; and the metal at the bottom of the pans is very liable to suffer, much in the same way as boilers do, from the precipitation of some sediment. It is found best to use pans lined with lead.

The boiling of the lye is carried on until all the superfluous water is driven off, and there is only sufficient left to retain the sulphate of aluminium in solution, even when it has completely cooled down. If it were carried beyond that point, the salt would begin to crystallise out, which would necessitate its being dissolved again preparatory to the next step of the process.

The concentrated liquor is run from the evaporating cisterns into large tanks, where it is allowed to become quite cold. Here it is that the potassic or ammoniacal salt is added, and, by combining with the sulphate of aluminium dissolved in the liquor, forms the double sulphate, alum, which, being only slightly soluble in cold water, is thrown down in crystals. To make potash alum, either the neutral sulphate or the chloride of potassium can be used; the latter article, familiarly known as "soap-boilers' waste," can readily be had in large quantities from the soap-works. In making ammonia alum, the refuse liquor from gas-works is used, which is converted into the sulphate of ammonium by treating it with sulphuric acid.

Having ascertained by testing the exact per-centage of sulphate of aluminium in the tanks, it is a matter of simple calculation to arrive at the quantity of either of these salts which will combine with it to make the double salt. This is dissolved in the smallest possible quantity of hot water added gradually to the liquor in the tanks, and the two mixed up together by vigorous stirring. As soon as they have properly combined, the alum is deposited in small crystals all round the walls and bottom of the tank, which is shovelled up and thrown out by the workman. After the mother liquor has drained off, the crystals are washed with as small a quantity of cold water as possible, to remove any adhering impurities. Some alum is necessarily dissolved off at the same time, but that can be again recovered, so that it is not wasted.

Both the purity and size of the crystals of alum can still be considerably improved, and therefore the process does not end here. This "first alum," as it is called, is boiled up with steam in a large stone cistern, water when boiling being able to dissolve about twenty times as much alum as when cold; it is then closed up, and left for about twelve hours to settle. The impurities which may have escaped the last operation having by that time found their way to the bottom of the boiler, the alum solution is drawn off into cooling tanks, where, as it cools, the alum crystallises out. A very perceptible improvement both in the whiteness and the size of the crystals will be seen at this stage, but it again passes through a somewhat similar process, which brings it up to the desired standard. The crystals are laid upon perforated shelves in a steam-chest, and again dissolved; as this proceeds the hot alum-liquor runs down to the bottom, and is drawn off through a pipe into the rocking-casks, where it is left to cool. The crystals soon cover all the sides, and gradually extend inwards towards the centre of the casks. These are then unhooped, and the staves removed, the mass of alum being left standing thus for several days to ensure that the crystallisation in the interior is complete. Some holes are then made in the side of the mass, by which to draw off the mother liquor remaining, and the alum is then ready to be sawn into blocks and sent to market. On the inner side the alum is then seen to be very beautifully crystallised, in large octahedral crystals.

In the foregoing description we have considered the ordinary processes of preparing alum; but the iron, which performs an important function in the first stage, is never entirely got rid of in the subsequent operations, the result being that alum contains about 0·12 per cent. of iron in the condition of ferric sulphate. Even this trace is objectionable in dyeing. An alum absolutely free from this impurity is prepared to some extent from cryolite, a mineral principally imported from Greenland, which is a double fluoride of aluminium and sodium ($Al_2F_3 + 3NaF$). The cryolite is heated with three times its weight of strong sulphuric acid, which reduces it to an anhydrous sulphate of alumina and acid sulphate of sodium, the hydrofluoric acid being given off; the sodium salt is washed out, and the sulphate of aluminium digested with warm water, to which sulphate of potassium is then added. The reaction is then the same as already described, and the pure alum crystallises out.

Some very good alums are made in the volcanic districts on the Continent, where earths rich in the most important ingredients are found, small crystals of native alum even occurring in some places. Some of the Italian alums are highly prized, on account of their purity.

In some countries alum is made with sodium, instead of potassium or ammonium; but it is not so convenient for the manufacturer, on account of being much more soluble in cold water.

The chemical constituents of alum are very widely spread in Nature; and at a price it could be produced in a great variety of ways, and from very different materials. It is not unlikely that some of these may one day be rendered more generally available. Felspar (a very common ingredient of igneous rocks) is a double silicate of aluminium and potassium, and albite of aluminium and sodium; both these can be converted into alum by replacing the silicic with sulphuric acid. Clay is a silicate of aluminium, and this also can be made available for the purpose, by treating it with sulphuric acid, and the addition of one of the alkalis.

WEAPONS OF WAR.—XI.

BY AN OFFICER OF THE ROYAL ARTILLERY.

RIFLED GUNS.

THE superiority of rifled guns in point of range and accuracy has been recognised by artillerists for more than two centuries back, and various have been the attempts during that period to construct pieces able to shoot elongated projectiles rotating on their longer axis; but these attempts one and all failed, in consequence of the backward state of mechanical and metallurgical science. It was not, however, till the general introduction of rifled small-arms during the Crimean War that rifled guns became actually necessary, in order that artillery might remain, as before, the principal arm on the field of battle.

"Such being the state of the case, it was indeed fortunate for the ascendancy of artillery that, owing doubtless to the spread of railways, suspension bridges, etc. etc., the requisite improvement in metallurgy and in mechanical appliances should have opportunely taken place in recent years. It is only lately that the manufacture of cast steel as a material for rifled ordnance has made rapid progress, whilst the difficulties which used to attend the forging of wrought iron in large masses were

so great that a heavy anchor was one of the greatest achievements of the forge-master until the comparatively recent introduction of steam-hammers enabled him to forge our modern monster guns; and, thanks to the able mechanicians of the day, we have now rifling machines so perfect and easily manipulated that the operator could, if he pleased, engrave his name in the bore of a gun, and, withal, so accurate is their action that they work true to less than $\frac{1}{1000}$th of an inch, a dimension which can now be very easily measured by means of a Whitworth's micrometer, but which is fifty times too minute to be ascertained by the primitive measuring instruments of the last generation of mechanics."*

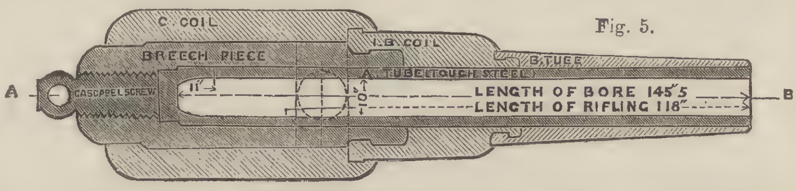


Fig. 5.

Our limited space prevents us going further into the reasons why a rifled gun should be made of stronger material and construction than a smooth-bore, beyond stating that the rifled gun is required to give a spiral motion to an elongated projectile about $2\frac{1}{2}$ times heavier than the *ball* which is simply projected from the smooth-bore gun of the same calibre (diameter of bore); so that there is a good deal more strain on the former description of gun than on the latter. We must say, however, that this increased strain could not, as a general rule, be met by merely increasing the weight of the piece, for it is a well-known fact that the strength of a cylinder is not in proportion to its thickness, and that in the case of a ponderous gun of a too weak material, the interior would be ruptured before the exterior portions could come into play.

Mr. (now Sir W.) Armstrong was the first in this country who brought a system of rifled ordnance to practical perfection. The principles of his gun-construction consist essentially—

"First, in arranging the fibre of the iron in the several parts so as best to resist the strain to which they are respectively exposed; thus the walls or sides of the gun are composed of coils with the fibre running round the gun, so as to enable the gun to bear the transverse strain of the discharge without bursting, whilst the breech end is fortified against the longitudinal strain, or tendency to blow the breech out, by a solid forged breech-piece with the fibre running along the gun. Secondly, in shrinking on the successive parts together with tensions so regulated that each part shall do its due proportion of work on the discharge of the piece; thus the outer coils contribute their fair share to the strength of the gun, whereas in an ordinary homogeneous gun the inner portions receive the brunt of the explosion, whilst the exterior ones are hardly affected by it at all.

"By a combination of these two principles (which are applicable alike to breech-loaders and muzzle-loaders) a gun is obtained which may be calculated to be twice as strong as a gun of the same weight and shape made out of a solid forging."

The first gun Sir William Armstrong brought to the notice of the War Office was a breech-loading 3-pounder, with poly-grooved rifling, and lead-coated projectiles—in fact, a type of what is commonly called the Armstrong gun. It was tried in 1855, at the School of Gunnery, Shoeburyness, in Essex, and made remarkably good practice at long ranges. Heavier guns of the same description were subsequently tried; and having proved their claims to accuracy, strength, and range-power, the excellence of the system was acknowledged, and the whole series of Armstrong breech-loaders, from the 6-pounder, of 3 cwt., to the 7-inch* (100-pounder) of 82 cwt., including the 9-pounder and 12-pounder field-guns, the 20-pounder guns of position, and the 40-pounder siege-guns, was issued for land service, and similar guns were also distributed through the different classes of vessels in the navy.

All these breech-loaders are made altogether of wrought iron, each gun consisting of a coiled inner barrel, a forged trunnion-ring, and one or more coils, according to its size; for example, the 6-pounder has only one coil, whilst the 7-inch has six.

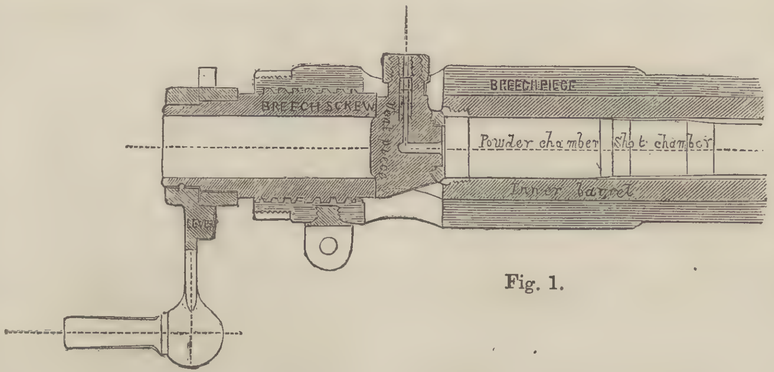


Fig. 1.

The gun is loaded through a hollow screw, called the "breech-screw;" the "vent-piece" (so called because the vent goes through it) is then dropped into the "slot," and the breech-screw being screwed up by means of the "lever," the breech is closed, and escape of gas completely prevented by means of copper rings on the face of the vent-piece and end of the barrel. The annexed illustration (Fig. 1) of a portion of the 6-pounder will explain the breech arrangement better than a page of description. The rifling is "poly-groove" (we are not responsible for the etymology of this word); and the "grooves" and "lands" are nearly of the same dimensions in all the natures, the only difference being in the number; thus the 6-pounder has 32 grooves (see Fig. 2), whilst the 7-inch has 76.

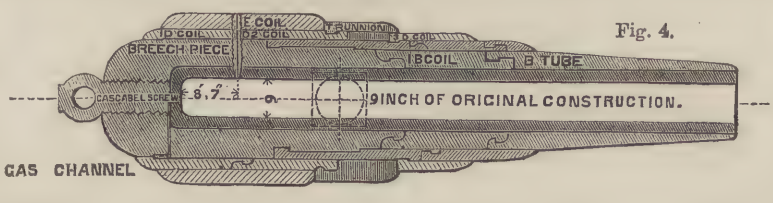


Fig. 4.

The Armstrong breech-loading guns were used in active service in China, New Zealand, and Japan, and answered remarkably well. Why, then, are muzzle-loaders more in favour? Because it has been proved by experiment that they are equal to the breech-loaders in range, rapidity, and precision of fire, and much superior to them in the simplicity of their fittings and ammunition, as well as in their non-liability to wear. There are, no doubt, advantages on the breech-loading side, and we think the Prussian field-gun, with the Krupp expanding wedge and the Broadwell copper gas-check, a simple and efficient breech-loader, but we do not think that any system of breech-loading has yet been found sufficiently safe, handy, and durable for heavy guns.

* This and the succeeding paragraphs in inverted commas are extracted from papers on the subject published in the Royal Artillery Institution Proceedings, by Captain Stoney, R.A., Assistant-Superintendent Royal Gun Factories.

* Below 7-inch calibre a rifled gun is designated by the weight of the shot and its own weight; 7-inch guns and upwards are designated by the calibre; and the weight is expressed in cwts., unless it is 5 tons or upwards, in which case it is expressed in tons.

In short, a breech-loading arrangement on a small scale, as in revolvers, infantry rifles, etc., is exceedingly convenient and satisfactory, but the difficulty of obtaining perfection of mechanism and ease of manipulation increases with the size of the weapon; and hence it is that when the introduction of armour-plated ships necessitated ordnance of great penetrative power, the British artillery authorities, after long and exhaustive experiments, adopted muzzle-loaders, and this leads us to our muzzle-loading rifled guns.

The largest gun in the English service is the muzzle-loading rifled gun of 35 tons, or 700-pounder, and the smallest muzzle-loading rifled gun is the steel 7-pounder mountain-gun, which was used in Abyssinia, and weighs only 150 pounds, that is, considerably less than a quarter of the weight of the projectile for the 35-ton gun. Indeed, it is absurd to see one of the big guns side by side with one of the little guns, and it is no wonder to learn that they are respectively spoken of as "Dignity" and "Impudence."

No other nation has got such powerful guns as we have. Herr Krupp, of Essen, the great German steel gun manufacturer, exhibited in Paris, in 1867, a breech-loader weighing 50 tons, and intended for a 1,000-pounder, but we believe it has never been fired. Russia and one or two other Continental powers have provided themselves with Krupp's steel breech-loaders, from 300-pounders downwards; while the remainder have followed our example, and adopted the heavy Armstrong muzzle-loaders for their ships and forts.

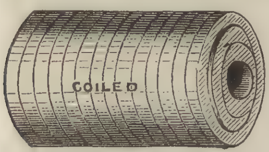


Fig. 6.

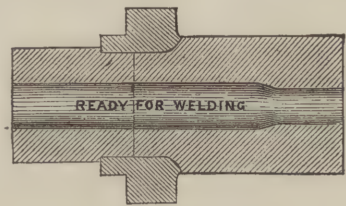
Fig. 8.


Fig. 7.

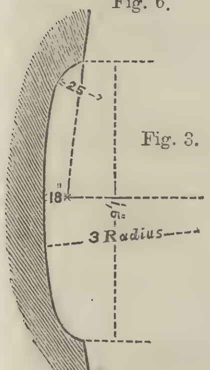


Fig. 3.

Fig. 10.

Fig. 2.

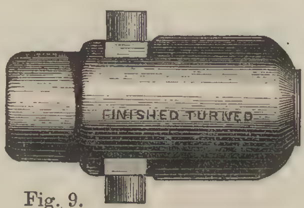


Fig. 9.

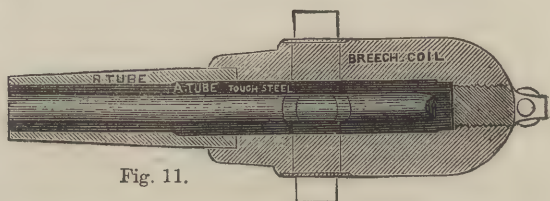


Fig. 11.

The 7-pounder mountain-gun is made out of one block of cast steel, bored out and tempered in oil; that is, the block of steel, after being roughly bored out for the barrel, is put into a furnace, where it is raised to a high heat, and then plunged into an adjacent bath of rape oil, in which it is allowed to cool and to soak for twenty-four hours. This process not only strengthens, hardens, and toughens the steel, but also increases its elasticity; and for a small gun the material so treated may be considered quite safe, and not likely to burst explosively. But a gun altogether of steel, even though thus improved, is of too snappish a nature to be trusted to bear the great and sudden shock of large discharges of powder, and so we deem it prudent to coil the steel round and round with wrought iron, after Sir William Armstrong's fashion; all our muzzle-loading guns,* therefore, from the new 9-pounder field-gun, of 8 cwt., to the 700-pounder, of 35 tons, are lined with steel (which, from its statical strength and hardness, is the best material we know of for withstanding the strain and friction on a rifled barrel), and have on the exterior coiled wrought iron, which, from its pliant and fibrous character, is capable of checking and counteracting any explosive tendency on the part of the steel.

Up to 1867 all our heavy muzzle-loading guns were built up with many coils, like the breech-loaders, and fired (as they do still) projectiles having two studs for each groove, the number of grooves increasing with the size of the gun—the 7-inch having three grooves, the 9-inch six, and so on. Fig. 3 shows a full-size section of the muzzle-loading groove.

"The 'Woolwich' guns built on this system, and lined with toughened steel, are sound and strong; but from the fine iron used, and the great number of exquisitely finished coils and a forged breech-piece, their manufacture was very costly; and as it was probable that several heavy guns would be required, the War Office pointed out the desirability of procuring some cheaper plan. Accordingly, the attention of the Royal Gun Factories was devoted to the question, and their efforts have been crowned with success. First, a cheaper iron, sufficiently strong for the exterior of the gun, was obtained; and, secondly, the plan which was proposed by Mr. Fraser, the principal executive officer of the department, was found to be less expensive than the original one.

"Mr. Fraser's plan is an important modification of Sir W. Armstrong's, from which it differs principally by building up a gun with a few long double or triple coils, instead of several short single ones and a forged breech-piece. There is less material, less labour, and less fine working, and consequently less expense required for the 'Fraser' or present service construction."

For example, in addition to the steel barrel and cascabel screw (breech-plug), a 9-inch gun of the Armstrong or original construction consists of a forged breech-piece, a B-tube, a trunnion-ring, and seven coils—ten distinct parts—shrunk on separately (Fig. 4); whereas a "Fraser" gun has only two, three, or four parts to be shrunk on, according to the size of the gun—the 7-inch and 8-inch having only two extra parts, the 9-inch three, and the 10-inch and higher natures four (Fig. 5).

From the fewer parts and the cheaper iron employed, the Woolwich guns of the present construction only cost about £70 a ton, whereas those built on the original plan cost £100 a ton.*

Without entering into the theory of construction, it must be sufficient to state that specimen guns of this cheap construction were tested to destruction, and were proved beyond all doubt to be as sound and durable as their original prototypes; and we have no hesitation in asserting that England now possesses the simplest, safest, and cheapest system of heavy ordnance in existence.

To give an idea of the way in which our heavy guns are built up, we will take as the simplest example a 7-inch gun of 7 tons.

* We have also 9-pounder field-guns altogether of bronze for service in India, and some 64-pounders converted from 32-pounder cast-iron smooth-bores, but these may be said to be exceptional pieces.

* A steel gun of Krupp's or Whitworth's plan costs about £170 a ton.

The gun consists of only four separate parts—namely, the A-tube, or inner barrel of steel, the cascabel, the B-tube, and the breech-coil.

The steel tube is bored out of solid ingot to within a few inches of the end; it is then toughened in oil, like the 7-pounder mountain-gun already described.

The cascabel is a forged block of wrought iron, with a screw-thread cut on it.

The B-tube is formed by two coils joined together, each coil being made of one long bar of wrought iron, brought to a high heat, wound spirally round an iron mandrel, and then longitudinally welded under a steam-hammer.

The breech-coil is somewhat more complicated; it consists of a triple coil, a trunnion-ring, and a front double coil, all welded together. The triple coil is made by winding three red-hot bars of wrought iron successively over one another, and then, having raised the mass to a white heat, welding it like the single coil, for the purpose of closing its folds (Figs. 6 and 7).

The front coil is made of two bars, in a similar manner. The trunnion-ring cannot be coiled, owing to the projection of the trunnions; it has, therefore, to be bored and formed out of a solid forging of wrought iron.

In order to join the three parts of the breech-coil into one solid mass, the trunnion-ring is expanded by heat, and dropped on a shoulder cut for it on the triple coil; the front coil is next dropped into the upper portion of the trunnion-ring, which is allowed to cool and contract, and thus bind the two coils together (Fig. 8). The mass is then heated and welded, and finally bored and turned to the proper size and shape (Fig. 9).

The parts of the gun being all ready, they are put together in this way:—The steel tube (having been finely turned) is placed upright in a pit, and the B-tube, which is just too small to go over it when cold, is heated and expanded, and is then dropped down on the chase end of the steel tube, which it grips in shrinking as it becomes cold (Fig. 10). The mass thus formed is inverted, and the breech-coil being heated, is shrunk on in a similar manner. Finally, the cascabel is screwed carefully in, and thus the gun is completely built up (Fig. 11).

Some of our early rifled guns were manufactured by Sir William Armstrong and Co., at Elswick, Newcastle-on-Tyne, where some cast-iron smooth-bore guns are still "converted" for the Government, on Major Palliser's principle—that is, an old smooth-bore, a 32-pounder, for example, is bored out and lined with a wrought-iron barrel, and converted into a rifled 64-pounder; but all our new guns, big and little, are now made in the Royal Gun Factories at Woolwich, where 6,000 tons' weight of guns of all calibres can be manufactured in one year. It may, however, fix our ideas better to give the actual guns which were made during the year 1871. They were as follow:—

12-inch guns, of	35 tons	(700 pounders)	13
11 "	25 "	(530 ")	19
10 "	18 "	(400 ")	83
9 "	12 "	(250 ")	46
7 "	7 "	(115 ")	28
7 "	6½ "	(115 ")	30
64 pounders, of	64 cwt.		35
40 "	35 "		20
16 "	12 "		160

All the above were wrought-iron muzzle-loading rifled guns, lined with steel. There were, in addition—

Bronze 7-pounder mountain rifled guns, of 3 cwt.	15
32-pounders, of 58 cwt., converted to 64-pounders	100

One projectile for the 35-ton gun (700-pounder) exceeds the weight of all those thrown from the whole broadside of a 74-gun ship in Lord Nelson's time. So much has the power of our guns increased since our last great naval battles!

PRACTICAL APPLICATION OF THE FINE ARTS.—III.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

THE MANUFACTURE OF COLOURED GLASS.

The manufacture of glass for coloured windows has improved very much of late years, yet it is confessed by one of the most successful of modern manufacturers that he has "never hitherto been lucky enough to find a single piece of modern glass equal for lustre and strength of character to the old manufacture." It is well that this spirit of humility should possess our manufacturers, and should urge them on to continued exertions after still more perfect glass. Yet they have acquired a considerable knowledge and dexterity in their work, and in many respects the results are as good as can be hoped for.

A great impulse was given some years back to those who supplied the glass-painters with the materials on which they were to work, by the researches and experiments of the late Mr. C. Winston. He not only procured careful chemical analyses of different kinds of twelfth-century glass, but he searched through the various records that have been left by old writers of the processes of manufacture. Further than this, he endeavoured to procure the materials from the very spots frequented by the workmen of old, and he employed Messrs. Powell of Whitefriars to try various experiments for him in the manufacture of different kinds of coloured glass. Some of these experiments were highly successful, and those manufacturers, together with Messrs. Hartley of Sunderland, and W. E. Chance of Birmingham, have profited greatly by the experiments of this amateur, and they, especially the latter, have since followed up the line of inquiry here indicated, and arrived at results sufficiently satisfactory, which, however, must be qualified with the reservation given above.

The process of manufacture is much the same as that adopted for the various other kinds of glass, such as that used for transparent windows and for glass vessels; the kilns and working pots are the same, and perhaps in this may arise some of the defects of the modern glass, for in the greater part of the glass required now-a-days, the chief object is perfect transparency and homogeneity; whereas in coloured glass, one of the principal beauties is the irregularity arising from air-bubbles and other imperfections. The early manufacturers made use of open pots; now the receptacles for the molten glass are entirely covered in, having holes at the side, through which the material can be extracted. The object of the covering is to keep out all kinds of impurities that might be carried into the pots by the furnace, especially gases which would favour the decomposition of the materials of which the glass is composed. Now, no doubt these occasional interferences with the manufacture caused the production of all kinds of irregularities, for Theophilus especially mentions that certain colours are to be obtained by the chance results of lengthy melting: we may conclude, therefore, that the open pots facilitated the production of great varieties, some portions of which would probably turn out valuable.

In another respect this manufacture differs from that of clear transparent glass. It was said before that the air-bubbles formed an additional beauty in coloured glass. Paradoxical as this may seem, it is really so, and the cause of the anomaly is this, that the air-bubbles "hold" the light; each little globe of air catches the beams as they attempt to pass through it, and refracts them with each change of medium, and in consequence the light which would pass obliquely through the pane is diverted in various tracks out of the direct line of the sunshine. This causes an appearance of glimmer frequently noticeable in ancient glass, and absent in much of modern, observably so in German, glass. In order to produce these air-bubbles, the glass has to be used before it is thoroughly cooked, that is, it is not melted so fully or so long as if it were intended to make it homogeneous and transparent. The effect of these air-bubbles may be seen on holding two pieces of similarly coloured glass in different positions in the direct rays of either sun or artificial light. Pieces of glass that seem to possess similar colour and brightness when seen against a plain sky, have very different effects when catching some of the slanting rays, according to the amount of irregularity in the texture of the glass. A variety, too, in the thickness of the pane adds a charm which is very pleasing to the eye, which would become very wearied by looking at a flat surface evenly coloured.

The composition of the glass is the same as that of a common glass of rather a soft character, the main portion of the materials being the same in all cases. This groundwork is usually formed of silica, carbonate of soda, carbonate of potash, carbonate of lime, lime, with a trace each of alumina, common salt, and sulphate of soda. To this common mass is added the various colouring matters. These are taken up and dissolved in the liquid glass without being chemically combined with it.

Coloured glass, therefore, is a kind of solution in glass of a metallic oxide not in sufficient quantity to make the glass opaque, but enough to give various degrees of colour. Blue is produced by the addition of oxide of cobalt in various quantities and in various degrees of purity. The impure oxide, just as it is procured from the mines in Germany, appears to produce the pleasantest tint. Oxide of iron is sometimes added, as well as that of manganese—materials which, in ordinary glass, have the property of nearly neutralising one another. A little oxide of copper, tin, and lead added to this, deadens the colour, and makes it deeper. It is in the blue glass, however, that the difference of the old glass from the modern is most observable. Probably, if the native oxide of cobalt, with all the impurities that naturally cling to it, were more frequently used instead of the imitation of the natural impurities made by the addition of other materials to the refined oxide, the old colour could be reproduced more exactly; for the ancients, who knew nothing of exact chemical methods, were apt to make use of those materials which came ready to hand, and which produced the results they required.

Protoxide of copper (Cu_2O) in very minute quantities, combined with the iron and manganese as before, produces a bright yellow glass. If used in larger proportions, and sometimes with protoxide of iron, it furnishes the deep ruby-red, which is such a striking and beautiful colour. The secret of the manufacture of this tint, which is one of the most successful, was for a long time lost, but was recovered about the year 1830, in France. A larger proportion of iron changes this red into a reddish-brown. Impure manganese, containing a considerable amount of iron, results in a kind of madder-brown; whilst a much paler glass of something of the same colour is produced by a smaller quantity of manganese with red lead instead of copper.

Various shades of green are produced by combinations of a great variety of materials, such as arsenic, nitrate and bichromate of potash, with the oxide of iron and copper mentioned above. These are the principal colours used at present. Slight variations of quantity in any of the materials change the tint, whilst differences of thickness in the glass itself, or in the proportion of the metal or common material of the glass, alter the tone and depth of colour.

When the materials have been sufficiently melted, and, as we said previously, before they have arrived at a perfectly homogeneous condition, the glass-blower takes a quantity of the metal, weighing some pounds, upon the end of what is technically called his *iron*. This iron is a rod or tube of some four or five feet in length, with a bore of about one-eighth of an inch. The lump of metal is blown into an oval bubble of some two feet in length, and when this is completed, the end farthest from the iron is opened by means of a *punt* (a solid iron rod, lighter and smaller than the *iron*), so that the glass assumes the form of a rough cylinder, which is now detached, by means of a cold iron, from the iron. The cylinder thus made is split down its length in the same manner as it was detached from the iron, and it is thus put on one side to cool. The next process is that of annealing, and this is accomplished by means of an air-oven, a low arched furnace fitted with iron trays filled with chalk or lime. On this lime the partially opened cylinders are placed, and when exposed to the heat, they gradually extend themselves until they lie flat upon the level bed of chalk. The metal, after the lapse of a few hours, is ready for use.

When it has arrived at this stage, the glass is usually of considerable thickness, frequently as much as a quarter of an inch, which is also the measurement of much twelfth-century glass; but the commoner sorts, manufactured in the earlier portion of the present century, were scarcely more than a sixth of this size.

Much of the ruby glass, and many of the brighter tints that partake of red, consist of what is called *flashed* glass. This variety is blown as follows :—The workman first dips his iron into a pot containing colourless, yellow, brown, or other metal, and when he has accumulated a sufficient quantity, he just dips the mass once entirely into the ruby metal, thus obtaining a coating of the red colour over the whole. This is then blown as before into a cylinder, which consists of a thick foundation of the principal metal with a thin coating of the ruby. This process gives a greater opportunity for modification of colour and tint, besides admitting of a variety of colour by removing the red surface, and either leaving the original glass beneath, or giving this latter a stain.

From what has been said above, it will be seen that some considerable amount of judgment is required in choosing the glass to be used in each particular portion. Those parts which have numerous air-bubbles are usually to be preferred on account of their holding the light; uneven pieces, because they are agreeable to the eye; pieces in which the colour is shaded, because it may so suit the design; thick glass, because it possesses a greater depth and richness of tone. Owing to the great impetus our manufacture acquired, partly from the researches of Mr. Winston and others, and partly on account of the increased demand for stained glass in England caused by the revival of a taste for ecclesiastical architecture, the English glass has become especially celebrated throughout the Continent, so that the Germans who have long been celebrated for the brightness of their colouring, and their manufactures in coloured glass, now come to England for the material wherewith to make their windows. Their own glass is found to be too flat, and consequently dull, though so highly coloured. If our manufacturers continue their course of steady perseverance and desire to excel, no doubt they will be able to hold their own against the world, but if they once attempt to pass off inferior glass, the evil will quickly recoil on their own heads. It is not sufficient merely to put together what appear to be the chemical ingredients of a particular glass: the source whence these ingredients come must be carefully observed, and the process of manufacture must receive the most patient attention.

MINING AND QUARRYING.—VIII.

BY GEORGE GLADSTONE, F.C.S.

IRON.

MANUFACTURE OF PIG-IRON — EXTENT OF TRADE—BLAST-FURNACES—DESCRIPTION—SIZE—CALCINATION OF ORES.

The smelting of the ironstone, by which the metal is separated from the other ingredients with which it is combined and formed into pig-iron, is a very large trade of itself; many ironmasters, especially in Scotland, do not undertake any of the subsequent processes to which iron is subjected in order to render it fit for use in the arts. Scotch pigs, of which no less than 1,180,000 tons were made in 1863, are well known as an article of commerce, and are sent to many parts of the world, just in the state in which they came from the blast-furnaces. It is estimated that the production of pig-iron in the British Isles is just about equal to the entire amount furnished by the rest of the world. The annual yield of the blast-furnaces in the United Kingdom now exceeds 5,000,000 tons.

Pig-iron is very rough in its exterior; within it is of a granular or crystalline structure; and it is usually very brittle. It is generally classified according to four qualities—Nos. 1, 2, 3, and 4—each having its own particular merits, according to the purpose for which it may be required.

The present article will be confined exclusively to the production of pig-iron.

The smelting of iron ores requires the adoption of a furnace capable of being raised to a very high temperature; a supply of fuel, and of limestone to serve as a flux. In order to stimulate the combustion, a strong current of air is forced into the furnace at the bottom, which, passing through the charge, makes its escape by the chimney; hence it is termed a blast-furnace. The pouring in of a current of cold air tended, however, to reduce the temperature in the lowest part of the furnace, just where it was needed to be hottest. To obviate this objection, the air is heated to a very high temperature on its passage from the pumping-engine to the furnace, which, by way of distinction from the other, is called the *hot-blast* process. This was the invention of one Neilson, a Scotch engineer, who took out a patent for it in 1828. It led to a great extension of the iron trade, coupled with an important reduction in the price of iron. The cold-blast is comparatively little used at the present time, as the iron thus made is much more expensive, though for quality it is highly esteemed by some people.

The form and nature of a blast-furnace for the smelting of iron has now to be considered at some length.

Fig. 1 represents the exterior elevation of a cupola or blast-furnace of the ordinary pattern. The former term is applied to the smaller ones, which are generally less solid in their construction, and cased with iron, though the principle upon which they are built is the same. Fig. 2 is a vertical section, and Fig. 3 a horizontal one at the level of the tuyere or twyer holes. The base, A, is generally firmly built of grit or sandstone, specially selected for its power of resisting heat. The arches, B, over the twyers, C, and the boshes of the furnace, D, are also built of the same material. The cone, E, is constructed of common bricks, but lined on the inner side with fire-bricks, a small space being left between, which is filled with sand. This arrangement is made to neutralise as far as possible the expansion due to the heat of the charge, which would otherwise be liable to loosen the brickwork. Sometimes the additional precaution is taken of binding the whole furnace exteriorly with hoops of iron, especially when it is desired to reduce the thickness of the brickwork. The charge is introduced through a door at the top of the cone, which is approached by the external gallery, F; and as the quantity of material which has to be brought up to this level is very considerable, it is generally so arranged that a tramway can be carried either on the level or by an inclined plane to this gallery, so that the charge can be tipped in from iron barrows. The angle made by the boshes, D, and also that of the cone, E, is a matter of importance, and depends to some extent both upon the character of the ironstone intended to be smelted and of the fuel to be used for the purpose; the great desideratum being that the charge shall not sink down into a mass at the bottom of the furnace till it has passed through a certain stage of the process, otherwise the action of the blast would be greatly impeded. A form more or less contracted towards the top is generally approved of (though many are, nevertheless, built with parallel sides), because the heat cannot otherwise be so well maintained in the upper part of the furnace. In the majority of more modern furnaces the boshes are carried up higher, and at a less angle than in the drawing; and some are made to curve gradually from the part where the width is greatest to the top of the hearth, G; the avoidance of any angle being for the sake of obviating the risk of any lodgment of the half-melted charge at the top of the boshes, which would occasion much trouble. The width of the hearth has latterly been considerably increased, which also necessitates, of course, a reduction in the size of the boshes. The throat, K, should be in diameter about one-half that of the extreme inner width; a narrower opening leads to an increased consumption of fuel, while at the same time reducing the make of iron. At the bottom of the hearth, G, in front of the lower orifice, H, is placed the tymp-stone, M, and plate, which is firmly fixed in its place, and the interstices filled in with clay. Between this and the dam-stone, which is immediately before it, is a small hole through which the molten slag flows out down an inclined plane, called the cinder-fall, shown at N, the hole itself being termed the cinder-notch. At the bottom of the dam-plate, and therefore communicating with the very lowest part of the hearth, is the tap-hole, which (except when the iron is being drawn off) is kept closed by ramming in sand. The tymp-plate, which thus forms the upper portion of the doorway of the hearth, is often made of iron, containing pipes inside, through which cold water is made to flow constantly to keep the plate cool. These are distinguished by the name of "water-tymps."

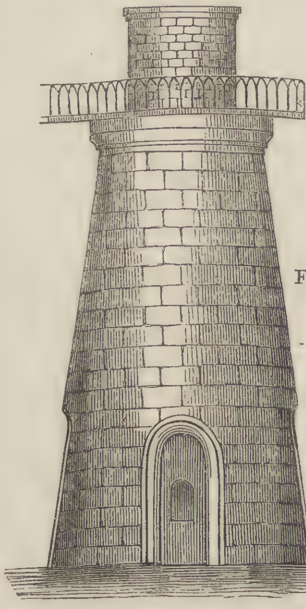


Fig. 1.

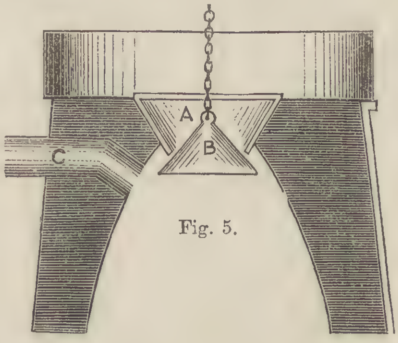


Fig. 5.

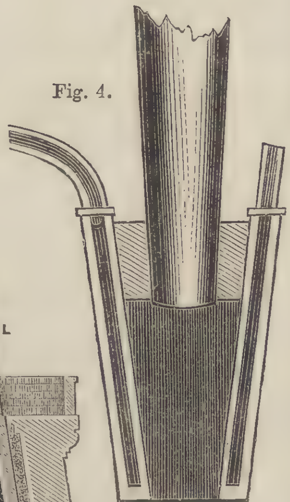


Fig. 4.

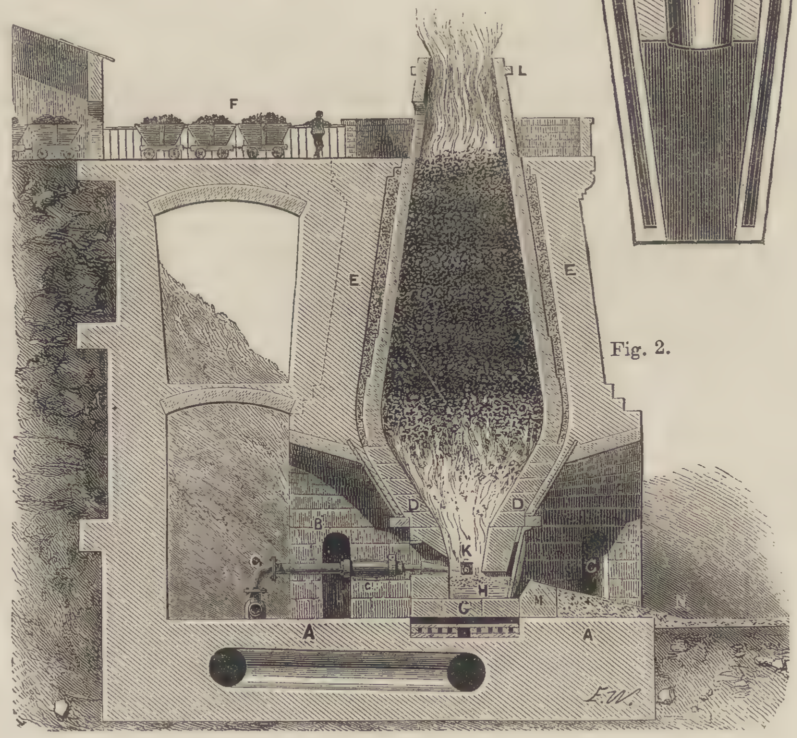


Fig. 2.

In front of the furnace, and opposite to the tap-hole, is a channel the use of which is to convey the iron as it runs out into the moulds, which are made of moulding sand, and are

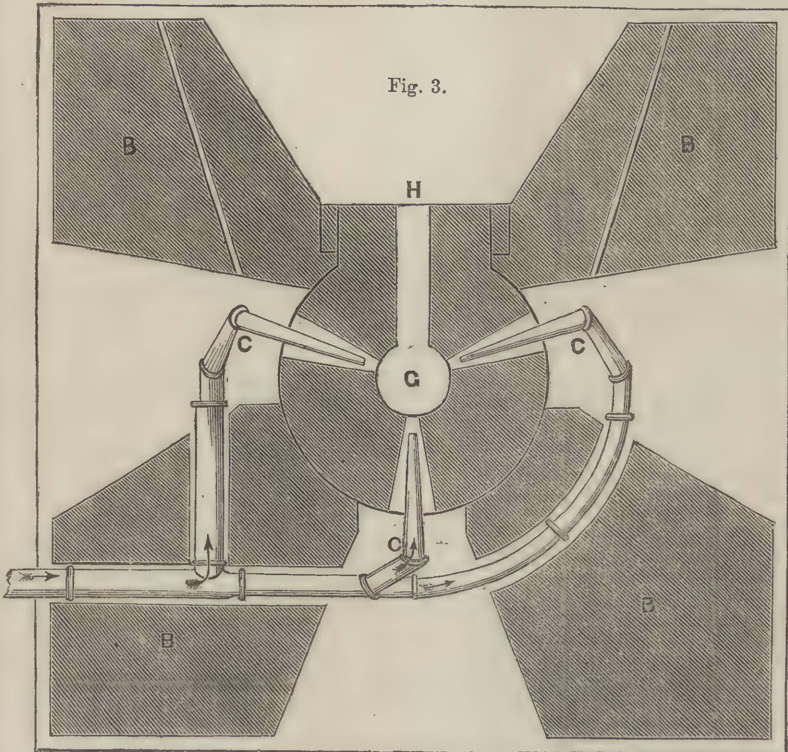
protected from the effects of the weather by being covered with a shed.

The twyers, C, convey to the furnace the draught of air necessary to promote the combustion. They vary in number from two up to a dozen or so, but three is very common, as shown in the diagram. Since the introduction of the hot-blast principle the twyers and supply-pipes are made of iron, and the nozzle is made of a hollow piece of wrought iron, as shown in Fig. 4, through which a stream of cold water is made to pass continually, in order to keep it cool.

The blast itself is produced by a steam-engine driving a piston in a cylinder which has valves opening inwards both at top and bottom, to admit the air, so that in both the ascending and descending stroke of the piston the air is forced out of the cylinder into a large receiving chamber, from which it again passes in iron pipes through the stove or oven to the twyers. The receiving chamber is made of a large size, so as to regulate the force of the blast, and render it continuous instead of spasmodic. From the receiver a pipe conducts the air through the heating oven, usually a close chamber with a furnace below and a flue above, the intermediate space being almost filled by the convoluted pipe so arranged as to present the largest possible surface to the heating power. Another short piece of pipe conveys the heated air from the oven to the twyers. The ovens are placed as near as possible to the blast-furnaces, so that the blast shall not have the opportunity of cooling in passing from one to the other. The greater the heat to which the blast is raised the better does it answer the purpose, as the requisite temperature of the furnace can then be maintained with a less expenditure of fuel. The heat of the blast should not be less than 600° Fahrenheit.

The chimney, L, extends somewhat above the charging gallery, in order to carry off the smoke and heated air which have passed through the charge; in some of the more modern iron-works, however, these heated gases are not allowed to go to waste, but are carried down again by a flue, and are made to serve instead of a furnace in heating the ovens just described. It is considered by some that the current of air through the furnace is thereby weakened, and that the temperature suffers in consequence; but it is maintained by others that this loss is more than compensated by the saving effected in the heating ovens. This requires a modification of the upper part of the furnace, and instead of having a chimney, an apparatus is substituted, called the "bell and hopper," which the accompanying drawing (Fig. 5) will serve to illustrate. Instead of charging the furnace through a door just below the chimney, the materials are thrown into the hopper, A, and then by means of a wheel and chain the bell, B, is lowered, when all the contents of the hopper fall into the furnace, and the bell is then drawn up again. The waste gases cannot escape in this direction, but are carried off by a pipe at the side, C, and are made to do duty as a source of heat.

Fig. 3.



A great deal of difference of opinion exists as to the best size of blast-furnaces, more especially as this depends very much on the character of the ore and fuel. In Scotland, for instance, though some have been built 65 feet high, the large ones are not found to work well, and a preference is given to those of about 50 feet. This is also about an ordinary size of the more modern furnaces in Wales and the midland counties. Such furnaces will have a capacity of 7,000 to 8,000 cubic feet. In the northern coal-field, however, coke of very great strength is produced, a cube of 2 inches each way being able to support (even when heated) a ton weight without being crushed; in the Cleveland district, therefore, where this very strong coke is used, the tendency has constantly been to increase the size of the furnaces, and the largest of them have proved the most economical in working. A few years ago, even in this district, 75 feet was the extreme height; but now there are blast-furnaces at work 85 feet in height from the hearth to the platform, 28 feet greatest internal width, and the diameter of the hearth 8 feet. These dimensions will give a cubic capacity of something over 30,000 feet; and each such furnace produces 490 to 500 tons of pig-iron per week, at a consumption of $20\frac{1}{2}$ cwt. of coke for each ton of iron made.

It takes a considerable time and expense to bring a blast-furnace up to the heat required; and when this is done the furnace is said to be "in blast," or "blown in." It is then maintained without intermission until, for the purpose of repairs, or because of the price of pig-iron being too low, it is found necessary or desirable to put it "out of blast." Being in blast, the smelting proceeds continuously; the charge is constantly supplied from the gallery above, as the contents sink down in the furnace; and the liquid metal, having trickled down through the mass into the hearth, G, is drawn off about every twelve hours, which is called "tapping the furnace."

The charge varies considerably according to the quality and nature of the ironstone, and also to some extent upon the character of the fuel used. The ore used always to be calcined or roasted first; and though this preparatory process is not so necessary now as it was before the invention of the hot-blast, it is still very generally done. This used to be accomplished by simply making a long heap of ironstone intermixed with small coal, and then setting fire to it at the windward end. It will gradually burn all through its length, just in the same way as clay is burnt for road-making. The calcining heaps, however, occupy a very great space, so that in the larger works it is more usual now to roast the ore in kilns very similar to those used for burning lime; they are rather more economical of fuel, and in hilly districts they are generally so situated that the door of the kiln shall be on a level with the gallery of the blast-furnace, so that the roasted ore can be readily wheeled from the one to the other. The blast-furnaces are therefore erected on the low ground at the hill-side, and the calcining kilns as near as possible at the higher level, the two being connected by a

light iron gallery. The calcining operation in kilns is a continuous one, the raw ore being put in at the top and the kiln kept full, while the roasted ore is withdrawn through the door below. The black bands of Scotland contain sufficient carbon to burn in kilns without the addition of other fuel; they lose from 40 to 50 per cent. of their weight during this operation, the calcined ore containing nearly 70 per cent. of iron. The clay bands lose less weight, and contain about 50 per cent. of iron after roasting. The loss of weight is due to the volatilisation of the water, carbonic acid, sulphur, and other ingredients. The roasted ore should be preserved from exposure to the weather, as it is liable to absorb again a great deal of water.

TECHNICAL DRAWING.—XXXVIII.

DRAWING FOR STONEMASONS.

A CONCISE HISTORY OF MASONRY (*continued*).

It was, however, different with the Roman masons; although, it is true, many of their temples were Greek in character, and most of them rivalled those of that nation in size and in the vastness of the material employed; the blocks of stone, for instance, in the architrave of the Temple of the Sun measure 16 feet 6 inches long, 9 feet 6 inches high, and about 6 feet thick, or nearly 50 tons in weight. But in general character there was less of that ponderous strength that characterised the Egyptian and Grecian Doric, and much more science in the construction—especially as regarded economy—whilst in point of artistic beauty the Romans were far below the Greeks.

The early Romans can scarcely be said to have possessed any style of building of their own; they for the most part borrowed their ideas from the Etruscans (who inhabited a part of Italy now known as Tuscany), and from the Greeks at a later period. In the time of Romulus their buildings would seem to have been of the most rude description, their dwelling-houses being composed principally of straw; and even at a somewhat later period their temples were only small square erections, scarcely large enough to contain the statue of their idol.

Ancus Martius was the first king who commenced works of a large class, requiring skill in their construction; and his first attempt was the building of the city and port of Ostia, at the mouth of the Tiber. Tarquin the Elder brought with him the skill and enterprise of the Etruscans, and set about improving the city with energy and perseverance. His first work was to erect the grand circus; he also constructed the walls of the city with large hewn stones, and commenced the great cloaca, or public sewer. This great work, which was considered to be one of the wonders of the world, was constructed of wrought stones, and was of such dimensions that a wagon loaded with hay could pass through it, and was carried through rocks and under hills, overcoming every engineering difficulty.

To whatever nation or race the invention of the arch may be attributed, it is clear the Romans were the first to bring it into general use, and they were the first in Europe to use the true dome in covering their temples. Besides this, they had not only good lime, but plenty of *puzzolana*,* and therefore their mortar and cement were of first-rate quality. To these advantages we may attribute the vast works which to the present day amaze the spectator, who cannot view the Roman cloacæ, aqueducts, amphitheatres, basilicæ, walls, towers, tombs, domes, harbours, etc., without wonder at the enterprise of the people and the skill of their masons.

As the whole subject of Gothic architecture forms a separate course of lessons, it is not intended here to enter fully into that subject, nor into the Byzantine, out of which it grew; nor the Saracenic, which was a rendering of architectural and ornamental elements under certain religious restrictions: a brief mention of the characteristic features of the period are therefore only necessary.

After the ruin of the Roman Empire, and the irruption of the savage hordes over the whole of civilised Europe, the art of masonry, like all others, declined to the lowest ebb. Had it not been, in fact, for the erection of rude forts and towers, it would have become extinct. In England we owe its revival to the Normans who came over with William I. in 1066; and next, no doubt, to the Crusaders, who had witnessed with admiration the marvellous lightness of the buildings in the East, and who brought back with them the arts and learning of the Arabians, especially their mathematical science. From these sources pointed architecture, no doubt, took its rise; and massive cylindrical pillars, composed of many small pieces of stone, small circular-headed windows, walls of vast thickness, with very shallow buttresses and plain groining without ribs, became changed to light-shafted piers and delicately-moulded arches, windows rich with varied tracery, panelled walls, with bold buttresses, surmounted by niches and crowned by pinnacles, and groined roofs fretted with a network of ribs, and studded with richly-carved bosses at the points where they crossed each other, were gradually introduced until the whole system of what has been termed the "Gothic" style was perfected.

In the sixteenth century a revival of classic architecture took place. The Gothic style had become much debased, and Roman or Italian styles were introduced into this country by Inigo Jones,* who was born in the year 1572, and whose distinguished works at Greenwich, Whitehall, and Covent Garden will ever secure him a place among names of the highest reputation.

Sir Christopher Wren,† an eminent mathematician, philosopher, and architect, executed very many of the finest buildings in London and other parts of England in the modern style. St. Paul's Cathedral in London, inferior to none but St. Peter's in Rome in point of magnitude, is justly considered one of the finest works of modern times. The exterior cupola of St. Paul's is constructed of oak, and is sustained by a cone of eighteen-inch brickwork, which has a course of stone the whole thickness—every five feet. Sir Christopher Wren formed an excellent school of masonry; the works at St. Paul's and other public buildings carried out under his superintendence being executed in a very superior manner. Besides this, with the assistance of

* Puzzolana is a substance formed of volcanic ashes more or less compacted. It derives its name from Pozzuolo, as also Pulvis Puteolanus, from Puteoli, situate near Mount Vesuvius, from which these ashes are ejected, and in the vicinity of which it abounds. It occurs in various colours—white, red, or black, reddish, or reddish-brown, grey, or greyish-black. That of Naples is generally grey; that of Civita Vecchia is more generally reddish, or reddish-brown. The red variety is the proper puzzolana; the black and the white sorts are called in Italy *lapillo* or *rapillo*. The ashes which overwhelmed Pompeii now form an immense bed of white puzzolana. The surface of this substance is rough, uneven, and of a baked appearance; it comes to us in pieces, from the size of a nut to that of an egg. When mixed with a small proportion of lime it quickly hardens, and this induration takes place even under water. The ancients were well acquainted with this substance and its properties, and among them its principal use, as it has been also in modern times, was that of mixing it with their cements for buildings sunk under the sea. As it hardens and petrifies in water, it is of particular service in making moles and other buildings in maritime places.

* Inigo Jones was born in the neighbourhood of St. Paul's, London, in 1572. His great aptitude for drawing attracted the attention of the Earl of Pembroke, who sent him abroad for four years to study the masterpieces of architecture in France, Germany, and Italy. In 1612 Jones re-visited Italy, further to improve his style, and on his return to England he was appointed Surveyor-General of the Royal Buildings. His masterpiece is considered to be the Banqueting House at Whitehall. He also built the church of St. Paul, in Covent Garden, Ashburnham House, Surgeons' Hall, Heriot's Hospital, Edinburgh (one of his finest works), etc. He died in 1653.

† Sir Christopher Wren, the renowned English mathematician and architect, was born in Wiltshire in 1632. He was educated first at Westminster School, and subsequently at Wadham College, Oxford. After the great fire in 1666, Wren drew plans for the entire rebuilding of London; few, however, of his recommendations were adopted. He was the architect of St. Paul's; and in 1710, in his seventy-ninth year, superintended the placing of the highest stone in the lantern by his son, the work having occupied thirty-five years. Besides this, he built fifty churches, the late Royal Exchange in 1667 [the present was built by Mr. (now Sir William) Tite, and opened by Her Majesty Queen Victoria in 1844]; the Custom House in 1668; Temple Bar in 1670; the Monument in 1671; the Royal Observatory, Greenwich, in 1675; Chelsea Hospital, 1690; Greenwich Hospital, 1696; Marlborough House in 1709, etc. He died in his chair in 1723, aged ninety years. The following inscription marks his tomb in St. Paul's—"Si monumentum quæris, circumspice" ("Dost thou seek his monument? look around").

Grinling Gibbons,* he formed an excellent school of architectural carvers. He was very particular in the choice of his stone. It is said that when the stone for St. Paul's had been quarried in the island of Portland, it was exposed to the weather on the sea-beach for three years before he permitted it to be used; and the result of his care is that amongst all his buildings there is scarcely a failure or a defective block.

The art of masonry was well upheld in the eighteenth century by Vanbrugh, Hawksmoor, Gibbs, and Lord Burlington. These were followed by Sir William Chambers, who built Somerset House; Dance, the architect of Newgate Prison; and Sir John Soane, who built the Bank of England. But shortly after cement works became so general that masonry suffered. "Besides this," says Mr. Ashpitel, "the heavy duties imposed on the transport of stone by sea, and the high prices which all material bore during the war, threatened to reduce masonry to its lowest." The revival of Gothic architecture has renewed the use of freestone, and has taught our masons the art of working tracery, groined roofs, flying buttresses, and such use of stone as was supposed, scarcely a century ago, to be one of the lost arts.

Besides this, the abolition of duties and the introduction of many facilities of transport by steam, both by land and water, have so reduced the price of stone, that in many places the use of cement is a false economy.

Further, the facility with which not only the upper classes but working men can visit other countries, has tended, whilst elevating the taste of employers, to improve the mental appreciation and manual skill of our artisans; and they have thus become qualified to execute the great monuments of skill which the present age has produced, and which will ever redound to the honour of our land.

The vast engineering and railway works—bridges, vaults, arches, and tunnels, the new Houses of Parliament, the lighthouses, exchanges, town-halls, churches, warehouses, etc.—which have of late years been executed in this country under the guidance of distinguished architects, have given such an impetus to the study and practice of constructive masonry, that a race of masons has been reared amongst us of higher and more varied skill than have perhaps ever existed in England, and even this standard is daily being improved by the efforts made for the promotion of the education of working men.

LINEAR DRAWING BY MEANS OF INSTRUMENTS.

Walling.—The work of the mason in this department calls for the continual exercise of skill and judgment, for he has not, like the bricklayer, to deal with blocks of a uniform size, but with heavy masses of all shapes and sizes, whilst the length, depth, and height of the walls he is building are all fixed.

The best or highest sort of stone walling is the easiest to set, for in it all the stones are tooled or gauged to regular sizes, to range in courses, and to suit the thickness of the wall to be built; and the most difficult is really that which is deemed the commonest, being that in which rough blocks are used, the mason merely chipping them with his hammer or axe, and fitting them in the best way he can, so as to form a compact mass. This is called *rubble walling.*

All stone is to a certain extent brittle, and therefore great tact is required in setting these irregularly-formed blocks, so that the ends may not be supported whilst the space between them is hollow; or that the stone may not rest on one projecting part whilst the ends are unsupported. If long pieces are used, they must be propped up in every part, lest they should break across, and thus occasion the whole superstructure to give way. And thus, although the object of the mason should be to form as compact a mass as possible, still that is done with the greatest safety when the strength is equalised; and, therefore, he will act the most judiciously in breaking a very long stone into two or more short ones, and working them in that state; for, by this means, he knows how to support or counteract the effects of the extra joint which he makes. Joints which may ensue after the wall may be finished would be irremediable.

The mason must bear in mind that whatever may be the quality of the stone to be used, the wall should consist of as much stone and as little mortar as possible. If the stone be inferior in durability and power in resisting the effect of the atmosphere to what the mortar will be when hard, no ulterior good will be gained, besides the certain fact that the mortar will yield until it has set hard, and thus the block resting on it will be, during the interval, constantly changing its place as others are placed upon it. And if the stone be (as it should) the more durable material, the more of it entering into the wall the better. The stones, however, should never be allowed to actually touch each other, any more than in brickwork; for where this might be the case, the mortar, shrinking in drying, would throw the whole pressure on the prominent parts, and so cause unequal bearing.

Bricks are wetted before working, for if the surfaces be covered with dry dust the mortar will not adhere; and further, they would absorb rapidly all the water out of the mortar, instead of allowing it to set gradually. Stone, however, being of a less absorbent nature than brick, it is not so important that it should be wetted; nevertheless, it is better that it should be in at least a damp state when it is worked, the adhesion of the mortar being then more certain and complete.

* Grinling Gibbons was of Dutch descent—if not, indeed, born at Rotterdam, concerning which there has been much dispute. He was born in 1648, and distinguished himself in carving at a very early age, when we find him living at La Belle Sauvage Yard, Ludgate Hill, the spot on which stand the works of Messrs. Cassell, Petter, and Galpin. Here he exhibited a pot of flowers carved in wood, so exquisitely delicate that the leaves vibrated as the coaches passed. He was subsequently recommended to Charles II., and executed a great portion of the carving in the chapel at Windsor. He also executed the carving in the choir of St. Paul's. He died in 1721.

APPLIED MECHANICS.—XVI.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

THE HYDRAULIC RAM—CENTRIFUGAL PUMP—CHAIN PUMP.

WE next consider the machines which depend upon the inertia of water, and first we shall discuss the very remarkable machine known as the hydraulic ram.

A diagram of the hydraulic ram is shown in Fig. 1. This figure will represent the principle on which the machine works.

P Q is a tube closed at the end Q, along which water flows, in the direction indicated by the arrow. This tube receives the water from a stream, and the object of the machine is to send a portion of the water up to a higher level. B is a valve, which is capable of being nicely adjusted; its weight is such that the ordinary pressure of the water beneath it is not sufficient to keep it closed. Thus the valve falls open, and the water flows out. The velocity with which the water flows is gradually accelerated while the valve is open, and the pressure consequently increases. When the pressure of the water attains a certain value, the valve B is pressed upwards and closed. The water which was flowing along the tube is thus suddenly checked. We have already learned that when a body is in motion it exerts a large force of resistance when its motion is checked. Water is no exception to this rule. The mass of water suddenly exerts a large pressure, and forces open the valve A. C is an air-chamber, in which the air is compressed; D is the pipe which carries the water to the height required. The pressure in the chamber C depends, of course, upon the height to which D is carried; but whatever be this pressure, the valve A will be forced open by the inertia, and a small quantity of water be driven into the air-chamber. When the water has come to rest, A shuts. The same operation is now repeated again; B drops open in consequence of the pressure not being sufficient, and the cycle again commences. Thus at each operation a small quantity of water is forced into the air-chamber C, and ultimately must ascend by the pipe D.

The inertia of water, which is so ingeniously applied in the hydraulic ram, has to be attended to in the fittings which are used in towns supplied with high pressure of water. Ordinary stop-cocks cannot be used on pipes in which the pressure amounts to 50 or 60 pounds upon the square inch. If the water be turned off suddenly, as it is by an ordinary cock, a rattling noise is heard, produced by the inertia of the water, and a violent strain is produced upon the pipes and fittings, which will sooner or later lead to rupture. The remedy is obvious. The force of inertia with which a body resists having its motion arrested varies according to the manner in which the motion is

stopped. If the motion be stopped suddenly, the inertia is prodigious; if the motion be stopped gradually, the inertia is very small. The plan is, then, to cut off the water gradually. This is done by using a cock in which, by means of a screw, the aperture is closed or opened gradually.

An improved form of hydraulic ram is shown in Fig. 2. The water flows from the source along the tube A; at B is the valve called the stoppage-valve, which is analogous to the valve B in Fig. 1. The stoppage-valve is shown open in Fig. 2; it is supported by a stem, and when not held up by the pressure of the water drops downwards to a distance regulated by a screw and nut. When the stoppage-valve is down the water flows outwards above the valve, until the velocity is so much increased that the pressure is sufficient to close the valve. When the stoppage-valve is closed the inertia of the water compresses the air in the space C. This air is called the air-mattress. The pressure which is produced by the shock is sufficient to force open the valves E, E and discharge some of the water into the outer chamber. From the outer chamber the water rises in the ascension-pipe, G, in the manner already explained. The valves E, E are then closed, the valve B descends, and the process again commences. The use of the air in the chamber is to act as a spring; for were it not for this spring the shocks would derange the machinery. As the air is soluble in water, it is necessary to supply air to the chambers, in order to restore the quantity which is taken away; this is effected by a small valve, H, which opens inwards, and admits air when the other valves are closed.

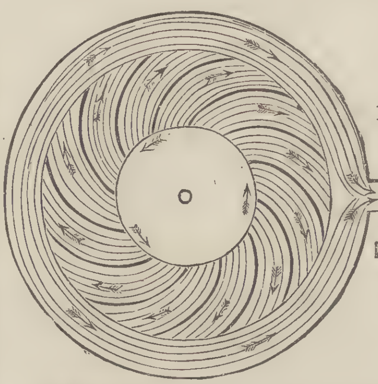


Fig. 3.

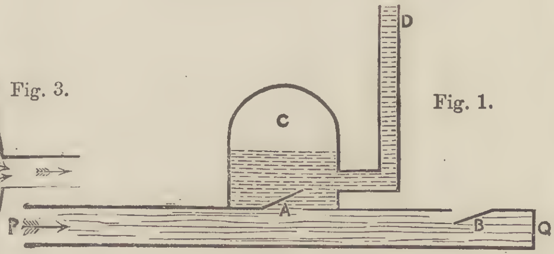


Fig. 1.

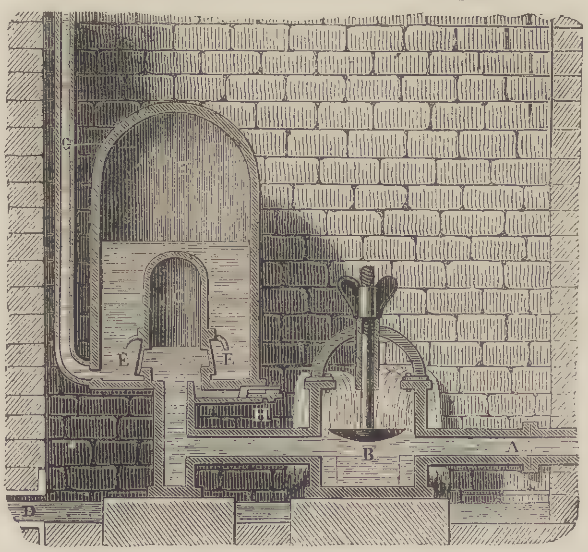


Fig. 2.

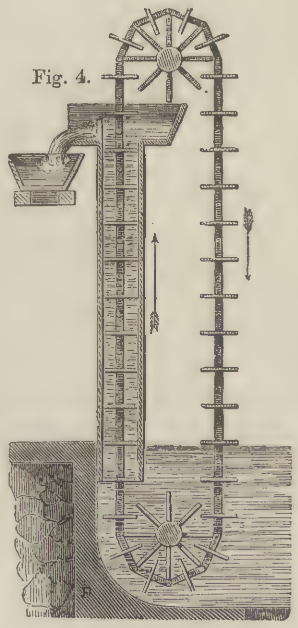


Fig. 4.

The hydraulic ram is periodic in its action, and so far resembles the pumps which we have been considering. It is principally employed when it is desired to raise a small quantity of water to a considerable height. It is frequently placed at the locks of canals, or similar situations, in which an abundant supply of water is available. The centrifugal pump, which we shall next consider, is a far more valuable machine than the hydraulic ram. It is capable, when worked with suitable power, of raising a vast body of water. It has, however, to be worked by a steam-engine, or other source of power, and so far is a more complicated machine than the hydraulic ram.

The centrifugal pump has very varied forms, which, however, all depend upon the same principle. We shall describe one of the most useful constructions, which is represented in Fig. 3. The water is introduced at the centre, O, from the lower reservoir from which the water is to be raised; from O the water enters by a series of openings into a wheel which is rapidly revolving in the direction of the arrows. This wheel is furnished with a series of blades perpendicular to its plane, thus dividing the wheel into channels, into which the water enters. When the water has entered the wheel, and becomes whirled round with it, centrifugal force drives the water along the channels to the circumference of the wheel, whence it finds an exit by the ascension-pipe.

In the construction of the centrifugal pump, particular care is required in the arrangement of the blades which form the channels along which the water flows; the efficiency of the machine depends greatly upon this point being attended to. What is required is to raise the water, and the energy of the engine which works the pump is to be devoted as far as possible to this purpose. The water, when it is raised, should be delivered with as little velocity as possible, for any velocity which the water possesses has been produced at the cost of the energy of the machine. Now the form of the blades is such that the velocity with which the water leaves the wheel is reduced to the smallest amount. The real velocity of the water is compounded of the velocity of the wheel with the velocity with which the water is flowing along the channels. By having the divisions nearly tangential to the circumference of the wheel the water is driven one way by its motion in the channels, and in the opposite way by the motion of the wheel; the consequence is that the water has really a motion only due to the difference of these velocities.

In Fig. 4 is represented what is called a chain-pump. This machine is very useful when a large quantity of water has to be raised. It consists of two wheels, the upper of which is turned by an engine, while the lower wheel is below the surface of the water. The chain which passes over the wheels is furnished with wooden boards, as shown in section in the figure. The water is raised by a rectangular case, which the wooden boards fit pretty accurately. This case goes below the surface of the water. As the boards are rapidly raised by the chain, the water is delivered from the top of the case.

TECHNICAL DRAWING.—XXXIX.

DRAWING FOR STONEMASONS.

RUBBLE—ASHLAR—RUSTIC WORK—ANGLE QUOINS, ETC.

WHAT "bond" is, and the necessity for it, has been fully explained and illustrated in lessons on "Building Construction;" and bond is of no less importance in stone than in brick walling; only a few further observations will, therefore, be added. It has been explained (Vol. I., page 97) that walling is broadly classified into rubble and ashlar, and although these have been illustrated, it will be useful to insert the illustrations again.

Walls are frequently built with mortar, which would have fallen under their own weight without it before they reached the height of six feet, in consequence of their defective construction, thus showing that they are held together merely by the mortar, which is very seldom a sufficient bond.

The student will scarcely require any particular directions in drawing Fig. 358. The base-line and the vertical edge will, of course, be drawn first, then the stones in all their irregularity. The description of the mode of building will then be the best guide in drawing the example. The sketch should be done very lightly in pencil, and a common writing pen may be used for the purpose of inking.

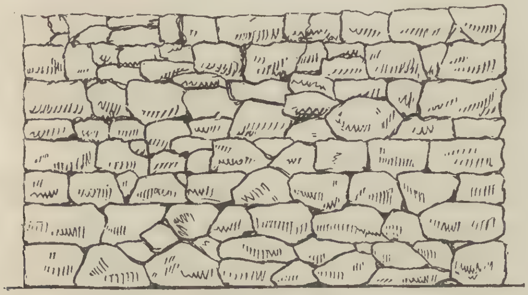


Fig. 358.

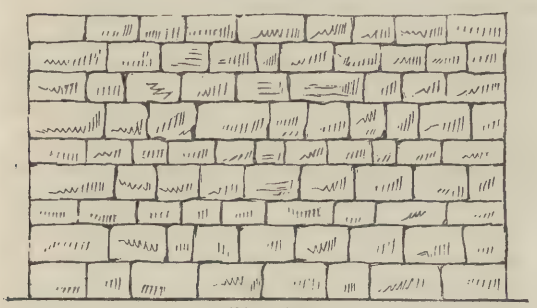


Fig. 359.

Fig. 360.

Fig. 361.

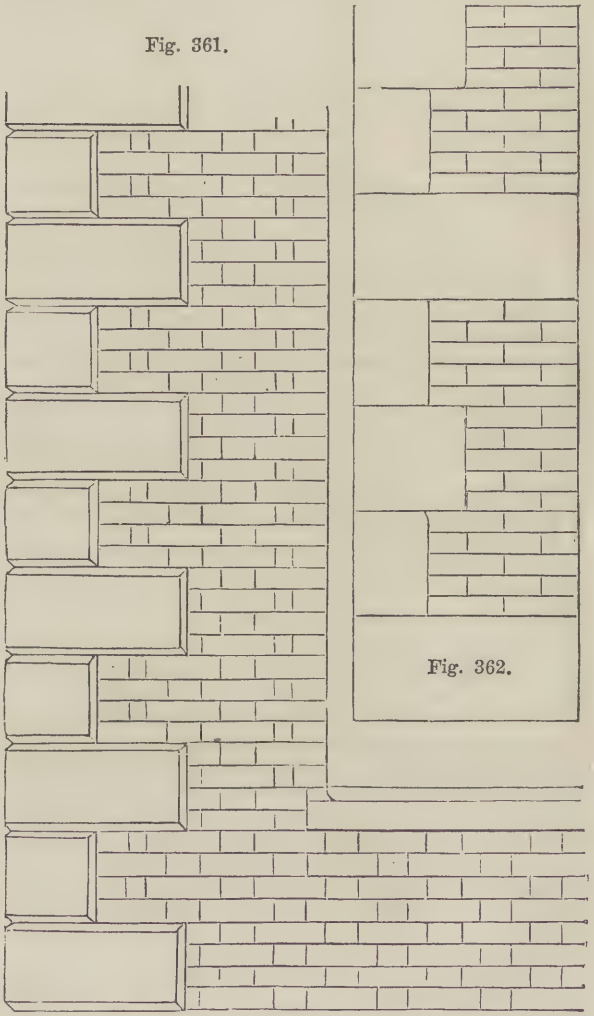


Fig. 362.

In rubble walls the joints, instead of being made to recur one over the other in alternate courses as with bricks, etc., should as carefully be made to lock, so as to give the strength of two or three courses or layers between a joint in one course, and one that may occur vertically over it in another. In bonding through a wall, or transversely, it is much better that many stones should reach two-thirds across, alternately from the opposite sides, than that there should be a few extending the whole way through, called "thorough stones." It is, in fact, much to be regretted that through a false economy walls are sometimes built of two thin scales, or faces, with thorough stones placed occasionally to tie them together, the core being made up of rubble and mortar. This mode of structure should be very carefully guarded against. There is no better test of a workman's skill and judgment in rubble walling than the building of a dry wall—that is, one without mortar—affords.

In drawing Fig. 359, coursed rubble, having drawn the base-line and vertical edge, the lines for the courses are next to be sketched, not *ruled*, for it will be remembered that the stones are rough dressed; the angle-quoins are, however, to be worked with greater neatness. All further information will be obtained from the preceding description.

Ashlar work (Fig. 360) must be carefully and accurately drawn, all the lines being ruled, and the widths of the stones measured. In drawing the whole elevation of a building, however, it is not usual to draw all the courses or single stones; a few lines freely but correctly drawn merely indicate the species of work employed. The method of using the various mathematical instruments, together with plain hints on linear drawing, has been given in "Projection" and "Building Construction," and, although we desire to make each of these courses of lessons complete in itself, it is obvious that to repeat

such elementary information in this place would necessarily curtail the information we desire to give on higher branches. Now as the two subjects referred to must be considered as the basis of the present study, the reader is urged to take them up either before entering upon, or together with this; and as all practical art is based on geometry, the system on which it is intended to base our instruction should be worked as follows:—"Practical Geometry applied to Linear Drawing," "Projection," "Building Construction," and "Drawing for Stonemasons." By this method the student will learn:—(1) The properties of various forms employed, their relation to each other, and the methods of constructing them in the readiest and most correct manner. (2) The manner of obtaining views of them as solids, instead of merely as plane surfaces; the shapes of sections in various directions, the development of their surfaces, etc. (3) The subject of construction as a whole, and the adaptation of materials; also the various kinds of drawings used by builders, and the method of executing them, and will thus be prepared to enter upon the branch specially his own with that interest which grows from systematic instruction. It has been the fault of our artisans to be content with merely the amount of knowledge they have obtained from each other, and to take interest only in that which related to their own immediate branch. This limited view of knowledge is at all times to be reprehended, but it is especially wrong in the trades relating to building, in which the artisans have to work so closely into each other's hands. Thus the work of the mason and the bricklayer meet, and both must work in concert with the carpenter, so as to arrange for his joists, girders, wall-plates, partitions, roof-trusses, and lintels, templets, etc. The carpenter must arrange so that his work shall suit the plumber, whilst it must almost imperceptibly glide into that of the joiner, who must again understand the requirements of the glazier, locksmith, etc. etc. It will thus be seen that no man can be said to be truly efficient who only studies his own occupation up to a rigidly-drawn line, and the necessity for men being mutually helpful and working harmoniously together is thus practically shown.

When ashlar work is smoothed or rubbed so as to take out the marks of the tools used in working, it is called *plane ashlar.* When the surface is wrought in a regular manner, like parallel flutes, and placed perpendicularly in the building, it is called *tooled ashlar;* but when the faces are worked with a broad tool, without care or regularity, the work is said to be *random tooled,* and when wrought with a narrow tool it is called *chiselled* or *boasted;* when the surfaces of the ashlars are cut with very narrow tools they are said to be *pointed.* When the stones project from the joints, the ashlar is said to be *rusticated;* in this kind the faces may have either a smooth or broken surface.

When walls are not entirely formed of masonry, in the ordinary course of economic building, stone is frequently used for copings, cornices, string and blocking courses, sills, landing, steps, stairs, hearthstones, chimney-pieces, etc.; several of these will be found illustrated further on, and we proceed to speak of quoins.

Quoin-stones are gauged and wrought blocks with parallel beds and vertical faces, placed at the angles of buildings with the intention of adding to their strength and beauty; they are used either with brick or stone walls, and are, as a rule, made to project beyond that to which they are attached. The quoins are covered with the rest of the wall, if it be of stone, and are made to occupy the exact space of a limited number of bricks in a brick wall.

Rustic quoins.—In these the edges are either bevelled, or the margins recessed in a plane parallel to the wall. The recesses, which are at the joints, have, therefore, three sides—one in the plane of the wall, or parallel to it, and the other two generally at right angles to this. Rustic quoins were much used in brick buildings at the end of the last and beginning of the present century.

Rustic work is a mode of building in imitation of simple Nature, rather than allowing the work to have the appearance of having been carefully finished by art. In this style, the stones in the face, etc., of a building, instead of being smooth, are hatched or pricked with the point of an instrument.

The most coarse or common rustic work is that where the edges are simply cut about one-half or two-thirds of an inch round the margin, so as to be in the plane of the wall, or parallel to it; and the intermediate part is broken with the hammer, so that the protuberant parts may project generally about an inch beyond the margin.

The recesses of rustics either run with the horizontal joints only, and the projections have, therefore, the appearance of boards placed at small intervals, or sometimes the recesses run with both the horizontal and vertical joints; and, therefore, when placed in this manner, they have the appearance of projecting tablets.

Rustic chamfered is that class of work in which the faces of the stones are bevelled at an angle of 135° with the surface of the wall, and as the joints are at right angles to the faces the margins will also be at 135° with the joints, so that when two rustics come together the bevelling or chamfering will form an internal right angle.

Rustic work frosted is that in which the margins are reduced to a plane parallel to the plane of the wall, and where the intermediate part has the effect of ice with an irregular surface in protuberant parts.

Rustic work vermiculated is that where the margins are reduced to a plane parallel to the plane of the wall, and where the intermediate part of the stone or general surface is so formed as to have the effect of being eaten by worms.

Fig. 361 is an illustration of angle-quoins with bevelled edges, each quoin occupying the height of four courses of brickwork. The student is advised to adopt a definite scale to work to. The elementary examples herein given, although generally correct as to proportions, are not worked to scale, in order that the student instead of merely measuring and copying the lines, may absolutely *work* the subject. It will be remembered that the general size of bricks is a trifle less than 9 inches long, $4\frac{1}{2}$ wide, and $2\frac{1}{4}$ thick. As there is, of course, some little space occupied by mortar, and for convenience of measuring, we here consider bricks 9 inches long, $4\frac{1}{2}$ wide, and $2\frac{1}{2}$ thick.

Having drawn the base-line and perpendicular, set off on the latter the heights of the quoins equal to four bricks, and draw horizontal lines; between each of these set off the heights of the separate courses of bricks. Now draw the vertical edges of the quoins, and also the double lines representing the chamfer, or bevel; the recesses at the outer edge and at the angles will be done by means of the set-square of 45°. The lines for the courses of the brickwork may now be drawn from the points in the perpendicular previously obtained. This plan is better than setting off the height of each course of brickwork from the bottom, in which plan the smallest error or inaccuracy is carried on and increased, whilst in the method here shown no error can extend beyond four courses.

In relation to the mixture of brick with stone ashlar in building, Sir Charles Pasley says that the stone should bear a definite proportion to the thickness of the brickwork in the wall, and mentions the British Museum, in which the stone is from 8 or 9 to 13 or 14 inches thick, in order to correspond with 1 and $1\frac{1}{2}$ brick.

In stone pilasters, projecting from the face of a wall having a stone front, the courses are usually equal to two of the other courses in height, or even more, it being the custom to make such pilasters of much larger slabs than the other portion of the wall.

Door and window jambs are also generally made in much higher courses, or even sometimes in one piece, which is by no means unusual.

As the joints in brickwork, being more numerous, are more liable to be compressed, and consequently that portion of the brickwork is liable to settle more than the stone front of the wall, it is prudent never to hurry the brickwork, but to carry it regularly all round the building by portions of a small number of courses at a time.

Fig. 362 represents a section of a wall having a stone front backed with bricks. In this example it will be seen that the stones are of the height of five courses of brickwork, and eight or nine inches thick, with some of twelve or thirteen inches thick intermixed with them, and "thorough" or bond-stones at intervals; the total thickness of the wall is equal to three bricks.

The method of drawing this example is precisely similar to the last: no further directions are therefore necessary.

SEATS OF INDUSTRY.—XIV.

NORWICH.

BY WILLIAM WATT WEBSTER.

Norwich, the capital of Norfolk, and a county in itself, is not only one of the most ancient cities, but it is also one of the oldest centres of manufacturing enterprise in Great Britain. Antiquaries disagree regarding the earlier history of the town. On the one hand, it is contended that Norwich was called *Caer Gwent* by the early Britons; that it was the capital of the Iceni; that Boadicea probably resided in the castle or fortress; and that it is the veritable *Venta Icenorum* of the Romans. On the other hand, it is maintained that Norwich rose out of the decay of an old Roman town, about three miles to the south, which, previous to the Roman era, was called Caistor, and is now known as Castor St. Edmunds. The latter, according to this view, was probably the *Venta Icenorum* of antiquity. There is a couplet to the effect that

> "Caistor was a city when Norwich was none;
> And Norwich was built of Caistor stone."

That a Roman camp existed at Caistor is not doubted; but it is alleged that it was placed there to guard the British settlement at Norwich, which was then a formidable stronghold. The name *North-wic* (the northern station or town) was conferred on the place by the Angles, the people who inhabited Northfolk and Southfolk; and by 575 it had become the capital of the kings of East Anglia. Records are in existence showing that the castle was occupied by Uffa, and that it was greatly improved by Anna, in 642, and by Alfred the Great, in 872. In the middle of the tenth century, Norwich was a large and wealthy town, divided into several distinct parishes; and in 1002 it was attacked and destroyed by the Danish fleet, under the command of Sweyn. It now became a Danish settlement, and the castle was rebuilt by Canute. At this period Norwich appears to have been an important fishing-town; and in the reign of Edward the Confessor it was a large, affluent borough. In Domesday Book it is stated that the city or borough had a mint, 1,320 burgesses, 25 parish churches, and from 800 to 900 acres of land. William the Conqueror bestowed the castle on Roger Bigod, one of his Norman followers, who is believed to have built the present keep; and it remained in the possession of his descendants till the reign of King John, when it was finally surrendered to the crown in 1224. In the reign of William Rufus, the bishopric of the East Angles was transferred from Thetford to Norwich; and the first stone of the celebrated cathedral was laid by Bishop Herbert, in 1096, the edifice having been completed by William Middleton, in 1284. Here we may note a remarkable natural change which took place in the vicinity of Norwich between the fifth and the middle of the eleventh centuries. Prior to the first of these dates, the town had been washed by an arm of the sea; but at that period the water began to recede, and by the year 1050 the channel had assumed the appearance it now presents. Henry I. granted a charter to Norwich containing the same franchise as London enjoyed; and the government of the city was then separated from that of the castle, the chief dignitary being styled *præpositus*, or provost. Up to this time Norwich would appear to have owed its chief importance to the fact of its being a stronghold; and its strength was greatly increased by Edward I. (Longshanks), who built walls round the town. The same monarch, two years later, gave the city the privilege of sending two members to Parliament; the franchise being vested in the freemen and freeholders not in receipt of alms, down to the passing of the Reform Act of 1832.

In the reign of Henry I. a colony of Flemish artisans settled at Worstead, in Norfolk; and this event may be considered the starting-point of the industrial history of Norwich, which thus dates from the beginning of the twelfth century. It is believed that these colonists were the first to introduce water-driven corn-mills, wind-mills, and fulling-mills into England; and that they revived the spinning and weaving of long woollen stuffs, and the art of building in brick, which had not been practised in the country since the withdrawal of the Romans. Portions of Flemish brickwork may still be seen in several of the old churches of Norwich and Worstead. There was a considerable number of Jews in the city of Norwich about the middle of the twelfth century, as well as in nearly all the principal seats of commerce in England, and especially in those situated on the east coast, which offered facilities for trading with the Continent. The Hebrews were wealthy, and their wealth excited the jealousy of the people. On the accession of Richard Cœur de Lion, in 1189, the Jews in London were massacred in great numbers by an infuriated mob, and the work of extermination was repeated at Norwich and other towns where they had settled, in spite of the attempts made by the king to protect them.

In 1328, Edward III. made Norwich the staple town of Norfolk and Suffolk for the sale of wool, wool-fells, and cloths; and about the year 1336 another and a larger body of Flemings migrated to the city, and added the weaving of worsted into cloth to its other industries. After this date the town appears to have made rapid progress, although its prosperity was frequently retarded by insurrections, plague, famine, and fires. During the reign of Richard II., discontent prevailed throughout the kingdom, and popular risings became general. Norwich was plundered and devastated by armed bands, which are said to have numbered collectively 80,000, led by Litester, a dyer. In 1403, Henry IV. separated the city from the county, constituting it a county by itself, and granting its inhabitants special and peculiar privileges. The doctrines of the Reformation were adopted in Norwich as early as 1422, and several Wickliffites, or Lollards, were executed there for heresy. By the year 1533 there were in Norwich twenty independent guilds, representing a much larger number of trades. The cloth-cutters, fullers, woollen and linen weavers, and wool merchants constituted one corporation; tailors, broiderers, hosiers, and skinners were united together in one guild; while the wax-chandlers, barbers, and surgeons formed a single corporation. It would appear, from an Act dated 1541, that the trade of Norwich had declined during the reign of Henry VIII. After stating that "among other cities, shires, and towns, having private commodities, the city of Norwich hath always heretofore been maintained and preserved, and that the poor men, and other dwellers and inhabitants, godlily, honestly, and virtuously brought up in the same, have been occupied and exercised by a commodity growing and rising only within the said city, that is to say, the making and weaving of worsteds and other cloths, which have been made and woven of yarn spun of the wool growing and coming of sheep bred only within the county of Norfolk, and in no place else; and whereas this trade has been of late craftily and deceitfully taken away by men buying up the wool of Norfolk, and sending it in a raw state to be manufactured in France, Flanders, and other places beyond the seas, and by reason thereof the city of Norwich and other towns in Norfolk are not only most likely to be brought to utter ruin and decay, but the inhabitants to be destitute of any way to get an honest living by," this measure enacts that no Norfolk wool shall henceforth be exported or worked up out of the county, under a penalty of forty shillings for every pound of yarn so exported or worked up. But this Act did not revive the drooping prosperity of the town, and the woollen trade remained in a depressed state for upwards of twenty years after it began to be enforced.

In the year 1549, the enclosure of certain commons and waste lands near Attleborough and Wymondham led to a rising similar to the Jacquerie in France, and the peasants' war in Germany. Under the leadership of a bold and resolute artisan, named Robert Kett, or Knight, a tanner, and his brother William, a butcher, the insurgent peasants and workmen laid siege to the city of Norwich. A camp was formed, and forces numbering 16,000, and including many of the city people, were collected. The hostilities continued for a month, and the country round Norwich was pillaged and laid waste. At length an entrance into the city was effected, and the mayor and several members of the corporation were taken prisoners, and carried to the camp as hostages. A strong body of troops, under the command of the Marquis of Northampton, marched to the relief of Norwich, but suffered defeat. The Earl of Warwick and his son, Robert Dudley, Earl of Leicester, were next sent against the insurgents; and after a conflict lasting two days, succeeded in defeating them, both sides losing about 3,000 men. Three hundred of the ringleaders of the rebels were executed on the spot, and the two Ketts were sent to the Tower of London, to meet the same fate. Again the Flemings poured into Norwich, and revived the prosperity of the town. The persecu-

tions of the Duke of Alva drove large numbers of Huguenots to seek refuge in England, and upwards of 4,000 of them settled in Norwich about the year 1561. But they had only fled from one form of persecution to encounter another, hardly, if at all, less cruel. The following paragraph from Mr. Smiles's "Huguenots" powerfully recounts that portion of the history of Norwich at which we have arrived:—"Although Norwich," he says, "had been originally indebted mainly to foreign artisans for its commercial and manufacturing importance, the natives of this city were among the first to turn upon their benefactors. The local guilds, in their usual narrow spirit, passed stringent regulations directed against the foreign artisans who had originally taught them their trade. Jealousy was excited, and riots took place against the Flemings, many of whom left for Yorkshire, to lay the foundation of the fortunes of several towns there; and Norwich, left to its native enterprise and industry, fell into stagnation and decay. The population diminished, riots were frequent among the distressed workpeople, and it was even mooted in Parliament whether the place should not be razed. Then the corporation determined to call to their aid the skill and industry of the exiles. In 1564 a deputation of citizens waited on the Duke of Norfolk, who succeeded in inducing 300 Dutch and Walloon families to settle in Norwich at his charge, and carry on their trades under a licence from the queen (Elizabeth). They restored the prosperity of the city; and in the course of a few years, 3,000 foreign workmen were found in Norwich, and many entirely new branches of industry were introduced and in operation. Besides sayes, bayes, serges, arras, mouchade, and bombazines, they introduced the striping and flowering of silks and damasks, which shortly became one of the principal branches of trade in the place. The manufacture of beaver and felt hats, which were formerly imported, was also successfully established at Norwich; and Anthony Solen introduced the art of printing, for which he was awarded the freedom of the city. Two potters from Antwerp also started a pottery there." But the antipathy of the citizens of Norwich towards the foreigners was not yet extinguished; and about the year 1570 a formidable conspiracy to expel them from the city was discovered, and its leader and instigator, John Throgmorton, was seized and executed, after which the refugees were allowed to follow their callings in peace. The foreign artisans enjoyed the favour of Elizabeth, who wrote from Greenwich in this same year, strongly expostulating with the inhabitants of Norwich against their foolish jealousy towards the authors of their prosperity. A census of the foreigners in Norwich, taken soon after this date, showed that they numbered 4,000, including women and children, and ten years later they were found to have increased to 4,679. Another immigration of foreigners into Norwich took place towards the end of the seventeenth century, the artisans in this case coming from France, and being skilled in the manufacture of silk goods, such as lustrings, brocades, tabinets, and velvets, while others made cutlery, clocks, and watches. In the Civil War, Norwich declared for the Parliament, and was occupied by its forces till Cromwell became protector. In addition to its great cathedral, the ecclesiastical history of Norwich is remarkable from the number of convents and other religious establishments that have flourished there, the funds of which have in most cases been diverted to charitable uses, and placed under the management of the corporation.

The manufacture of cotton was introduced into Norwich in 1784, and the close of the last century seems to have been the period of greatest prosperity in the history of the town. It has been estimated that the value of the goods exported from the city at that time to the East Indies, Russia, and other countries (consisting chiefly of camlets and camletees, callimancoes, worsted satins, figured stuffs, lustrings, damasks, and shawls) amounted annually to £1,000,000, or about one-fourteenth part of the British manufactured goods exported at that period. Since that date Norwich has been outstripped by rival manufacturing towns in Lancashire and the West Riding of Yorkshire, which have enjoyed greater advantages, on account of their proximity to rich coal-fields and the absence of corporation privileges. Many articles formerly peculiar to Norwich are now manufactured at cheaper rates elsewhere; and the greater part of the yarn worked into fabrics at Norwich is spun at Bradford. The worsted manufactures of the West Riding are now far more extensive and valuable than those of Norfolk. In 1719 a new silk and worsted fabric, called Norwich crape, was invented, which rapidly became so fashionable, that during Walpole's administration court mourning entirely consisted of it. There were about 1,000 persons employed in the mills for throwing silk at Norwich in 1810.

The close and influential connection of the Gurney family with Norwich throughout many centuries entitles them to a place in a sketch of that town, however brief, and their story forms an important chapter in the history of British commerce. As Mr. Bourne has remarked, in his "English Merchants," we see in the Gurneys "the almost solitary instance of an ancient family that in later times has not been ashamed to engage in commerce, and has drawn from it a dignity as great as any that could come from lengthy pedigrees and the traditions of bygone ages." The founder of this house in England, Hugh de Gournay, Lord of Gournay and Le Brai, held an important command at the battle of Mortimer, in 1054; and coming to England with the Conqueror, in 1066, was awarded large grants of land in Norfolk and Suffolk. It would appear that the first of the family who settled in the town of Norwich was Edmund Gournay, who, in the time of Edward III., held an office corresponding to the recordership. Since that date some members of the family have always resided at Norwich, and several of them have greatly contributed to its prosperity. Towards the close of the seventeenth century, John Gurney was for thirty years a famous and highly successful merchant in Norwich. After serving an apprenticeship to a cordwainer in the town, and suffering three years' imprisonment in Norfolk Gaol on account of his having in his twenty-third year adopted the doctrines of the Society of Friends, John Gurney started in business as a merchant and manufacturer, and, at a later period, as a sort of banker or money-lender. He supplied silk to the Palatines and other foreign refugees in Norwich, and built a silk-mill there, on the model of the celebrated silk-mill of Sir Thomas Lombe, at Derby. When he died, in 1721, at the age of sixty-six, John Gurney left a considerable fortune and a very profitable business to his sons, John and Joseph, in the accumulation of which he had been ably assisted by his wife, who, it is alleged, was the real founder of the commercial greatness of the Norwich Gurneys. The sons carried on the business with great success; and John became known in his day as "the famous advocate of the weavers," he having been instrumental in obtaining the passing of an Act dated 1721, "to preserve and encourage the woollen and silk manufacturers," which prohibited the use or sale of cotton clothing, under a penalty of £5 for the offence of weaving, and £20 for selling any cotton garment. It was the two sons of the "weaver's advocate," John and Henry Gurney, who founded the Norwich Bank, they having, in 1770, converted their old dwelling-house, in Saint Augustine's parish, into a banking-office, and from that date devoted themselves exclusively to banking transactions. In 1779 the business descended to Bartlett Gurney, Henry Gurney's son, who removed it from the original premises. Three cousins and others were adopted as partners, and on the death of Bartlett Gurney, in 1802, the concern came into their hands. Of the three cousins the most remarkable was John Gurney, born in 1750, the father of Elizabeth Fry, Lady Thomas Fowell Buxton, Joseph John Gurney, the philanthropist, and Samuel Gurney, the millionaire. It was about the year 1800 that the celebrated house of Richardson, Overend, and Company was founded, through John Gurney's assistance; and in 1807 the firm was greatly strengthened by the introduction of his son Samuel as a partner. Until the death of John Overend occurred, however, the connection of the Gurneys with the firm was kept secret, but after that event it assumed the world-famous title of Overend, Gurney, and Co. The story of this firm hardly comes within the scope of this paper; but, to complete the outline, it may be mentioned that the establishment, which had been left in a position of almost unexampled wealth and influence by Samuel Gurney, who died in 1856, one of the richest men in England, was reorganised as a joint-stock company, under the "Limited Liability Act," in 1865, and failed on the 18th of May, 1866.

In addition to its worsted and silk factories, Norwich contains iron and brass foundries, snuff-mills, vinegar-works, dye-works, corn-mills, malt-houses, breweries, and oil and mustard mills; and of late years the manufacture of ladies' boots and shoes has been extensively carried on there; this having, indeed, become one of the staple trades of the city. In the latter

branch of industry women and children are principally employed, but a considerable number of men are engaged in it as well. The making of agricultural implements is also prosecuted at Norwich with great success. Since 1833 the commerce of the city, which consists chiefly in the export of manufactured goods and agricultural produce to London and other ports—its foreign trade being inconsiderable—has been greatly facilitated by means of canals connected with the Lowestoft navigation, which give vessels drawing ten feet of water direct access to the town from the sea.

Norwich is situated on the river Wensum, immediately above its junction with the Yare, and is twenty miles W. of Yarmouth, and ninety-eight miles N.N.E. of London. Seen from a distance, its appearance is very striking; and it has long been called "the city in an orchard," owing to the unusually large proportion of garden-ground which surrounds it. Portions of the old walls and towers are still in existence, and there are many objects of interest to the antiquary in the city. The cathedral, which did not assume its present shape till the sixteenth century, is one of the largest and finest ecclesiastical edifices in the kingdom. The style is almost purely Norman. It is cruciform in structure, and from the intersection of the cross formed by the nave, choir, and transept, springs a lofty Anglo-Norman tower of four stories, highly ornamented, and surmounted by an elegant spire, rising 315 feet from the basement of the church. The west entrance is extremely beautiful, notwithstanding that the more salient ornaments have begun to moulder away, and it is from this point the best view of the pile can be obtained. The interior of the cathedral is exceedingly imposing and grand, but the architecture is of various periods, from the Anglo-Norman to the English Perpendicular, and modern alterations have not in all cases been improvements. The roof is divided by fourteen semi-circular arches, and there are 328 elaborately sculptured figures of Scriptural subjects among the decorations. Its cloisters are also remarkable, both for their dimensions and embellishments. Near the cathedral are several ancient and valuable specimens of architecture; and the city contains about forty churches, and about twenty-two dissenting chapels and other places of worship. St. Peter's, Mancroft, is a large and handsome cruciform edifice, dating from the fifteenth century, with a noble tower ninety-eight feet high, containing a peal of twelve bells, considered one of the finest in England. Among the charities of Norwich, the most noteworthy is St. Giles's Hospital, which is maintained by rents and other property yielding an average annual revenue of some £7,000. It provides clothing, food, and a small stipend for 165 inmates, exclusive of servants. The Free Grammar School of Norwich was founded by Edward VI., and possesses endowments amounting to about £200 per annum, and a fellowship at Caius College, Cambridge. There is a public library in the city containing 20,000 volumes, and the library of the Norwich Literary Institution consists of 15,000 volumes. In 1821, Norwich had 50,288 inhabitants; in 1831, 61,110; in 1851, 68,706; in 1861, 74,891; and in 1871, 80,390. Many of the streets are new and handsome, but, as a whole, the city is indifferently built. The houses are nearly all of brick, and in the older quarters are more remarkable for their age than for their beauty or comfort. There are in the town and vicinity ten bridges; and the market-place is one of the largest in Great Britain, being 600 feet long, by 340 feet in width.

FARMING AND FARMING ECONOMY.—III.

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MITIGATION OF PHYSICAL CONDITION OF SOILS—MANURES—FARM-YARD MANURE, GUANO, SUPERPHOSPHATES, ETC.

SOIL, like other substances, possesses physical properties and a chemical constitution. Physical properties have relation to those features which are discernible to the senses in any body, simple or complex. Thus a piece of chalk is white, comparatively soft, has a definite specific gravity, and certain relations to heat, light, electricity, moisture, etc. In the same manner the soil, whether it bear the character of a retentive clay or a blowing sand, has physical attributes well worthy of the farmer's consideration. Its colour exerts an influence upon its temperature; its tenacity has an important effect in its relations to moisture and to growing plants, as well as upon every tillage operation; its relations to heat and moisture have much to do with its fertility; while if we take into consideration the physical conditions under which it is placed, we shall see the importance of climate, of inclination or slope to the north or south, and of the relation of soil to subsoil. The study, therefore, of the physical properties and conditions of soils is most important, especially as means exist for, to some extent, modifying them.

As drainage, clay-burning, and mixing are processes by which the physical condition of soils may be mitigated, so the application of manurial substances is the means by which their chemical condition may be improved. In other words, while the soil is put into the best possible mechanical condition by the first class of improvements, it is enriched and stored with plant-food by the second. Although the means of improving land may be thus divided into two classes, they imperceptibly glide into each other. Thus, while marling exerts a direct effect in altering the physical condition of a soil, it also enriches it with valuable mineral constituents. Even farm-yard dung, the typical manure of so many farmers, may be shown to act both mechanically and chemically upon the soil. The mechanical action of ordinary farm-yard dung was strongly believed in by Jethro Tull, who attributed its usefulness entirely to its causing the further disintegration of the soil during its own decay. Numerous other substances applied to land exert this double effect, and thus improve the physical condition of the soil while they increase its store of plant-food. There is, therefore, some danger of confounding these two actions with each other, and it becomes necessary to clearly define the meaning of the term "manure." The usual dictionary explanation of the word is scarcely strict enough for our purpose; and we cannot agree with Webster that a manure is anything which fertilises land, for if this were the case then would the ordinary tillage operations of the farm come under the definition. Manuring consists in applying substances to the soil which subsequently may be employed by growing plants in building up their tissues. The repeated growth of crops removes plant-constituents from the soil, which it is found necessary to restore by the use of manures. It is of importance to bear in mind that the value of a manure depends upon the extent to which it is able to replace the constituents removed from the soil by crops. It is, therefore, no matter of wonder that farm-yard manure, composed as it is of the excrements of highly-fed animals and decaying vegetable matter, should be a highly-valued fertiliser. Such a substance, when made under the most favourable conditions, contains in an available form every necessary constituent of both corn and straw, and is eminently adapted both to keep up and increase the fertility of land. Other substances have of late years been introduced to the notice of the farmer for the same purpose, and the use of artificial manures is one of the principal features of modern farming. Artificial manures owe their origin to the light which chemistry has thrown upon the practice of agriculture. No sooner was it discovered that fertility was in a considerable degree due to the presence of certain definite substances in the soil than the idea arose that fertility could be maintained by the artificial application of those substances. Hence ammonia salts, nitrates, phosphates, potash, and magnesia salts began to be successfully employed in agriculture, and the manure trade became an important part of our commercial life. Artificial manures have supplemented, and to some extent superseded, the use of farm-yard manure. It is important to bear in mind that the value of a manure consists in the amount it contains of a few chemical substances. This is a lesson which farmers are somewhat slow to learn; and a sort of superstitious veneration still exists for farm-yard dung, composts, vegetable and animal matter, or, in fact, anything which combines bulk, "greasiness," and a bad smell. It is, however, only chemical analysis which can truly indicate the quality of a manure; and the basis upon which the chemist makes his estimate is the per-centage of certain fertilising elements. The question of farm-yard and other "natural" manures, *versus* "artificial" fertilisers, is capable of scientific solution. Farm-yard dung is always a safe, although occasionally an extravagant, application to land. It is difficult to make a mistake in using it; whereas the proper use of artificial manures requires considerable knowledge of the requirements of plants and the nature of soils. That fertility may be maintained and increased by artificial manures alone has been fully proved

at Rothamsted, by the long-continued experiments of Mr. Lawes and Dr. Gilbert upon the growth of wheat. This is a case in which wheat has been grown, under a variety of circumstances, upon the same land consecutively for twenty-eight years. The field is divided into plots, each of which has received a different treatment; and from all of them both straw and grain have been constantly removed for the period above named. A plot constantly unmanured has given a low average of 14¾ bushels per acre; a second, manured annually with 14 tons per acre of farm-yard manure, 35½ bushels per acre; a third, manured with an artificial combination of all that the plant requires, has yielded an average of 36½ bushels per acre, and has been greatly improved in productive power since the commencement of the experiment. The above averages are for seventeen years, between 1852 and 1868. Similar trials upon barley for the same period confirm the fact that a soil may be fully supplied with manurial matter by means of artificially produced chemical substances. Hence we have good reason to believe that the boasted dictum of "the more stock the more corn" is incorrect, and that there is no essential relation between feeding animals and growing corn-crops.

Manures have been divided into two classes—*general* and *special*. A general manure is a substance containing all the necessary constituents required by growing plants. It is therefore able to keep up and increase the fertility of a soil. A special manure, on the other hand, does not contain every necessary constituent, and occasionally only one or two of them. Such a substance is, in a qualified sense, exhausting to the soil when frequently applied. Take, for example, the two cases of farm-yard manure and "nitrate of soda," the first a general, and the second a special manure. Repeated dressings of the first would enrich the soil; but repeated applications of the second would, by stimulating the growth of the crop, tend to rob it of phosphoric acid, potash, and all valuable constituents except nitrogen. Nitrate of soda contains no phosphoric acid or potash, and these being removed in greater quantity by plants manured with the nitrate, repeated dressings of this substance would be followed by a diminished store of other plant-constituents. This is no reason for discontinuing the use of nitrate of soda as a manure, for a good farmer will supply phosphoric acid and other constituents in due course, and the supply of all necessary manurial substances will be kept up in the soil.

Special manures are useful under three classes of conditions. First, when applied to crops which have special requirements, as, for example, when potash is used for potatoes, or common salt for mangel-wurzel; secondly, when a soil is deficient in some particular constituent, such as lime or magnesia, the addition of which will cause it to approach nearer to the standard of a perfect soil; thirdly, when it is employed to realise a store of fertility already accumulated in the soil. This last case is best illustrated by a wheat-crop growing upon land in high condition from previous manuring. Here, nitrate of soda may be applied with great advantage, as it will at once cause the wheat to grow vigorously, and to remove from the soil plant-food which would otherwise have remained dormant. Thus may nitrate of soda and other special manures be employed as a means of quickly recovering the farmer's capital from the land.

It may readily be shown that the continued use of a general manure is not always economical. If, for example, we continue year after year to dress a field with farm-yard manure, while we add to it all that is necessary, we are probably also adding more than is necessary. Certain substances will accumulate in the soil in excess of what is needed; and a rational system will point out the advantages of using some special manure, so as to realise the store of fertility now present.

Farm-yard manure, the oldest, and probably still the most important manurial substance employed in agriculture, is exceedingly variable in its composition. Its basis is the food and litter with which the animals producing it are supplied, and it will be found to vary in quality according to the circumstances under which it is formed. Thus the age of the animal is important, the manure of young, growing cattle being inferior to that of older stock; the kind of animal, whether it be a horse, ox, sheep, or pig; the condition of the animal as to fatness or leanness, and the quality of the food given, all exert their influence. The proportion of litter to the solid and liquid excrements, the amount of shelter from rain and snow during its formation, and the after treatment to which it is subjected, all bear upon the value of farm-yard manure, and render the formation of the best dung a complicated question. The best farm-yard dung is obtained by mixing the manure produced by various animals maintained on the farm. Horse-dung is proverbially hot, being comparatively dry and rich, and quickly ferments and becomes mouldy. Pig-manure, on the other hand, is considered cold in its nature, and the excrements of both these animals are improved by being mixed with that of cattle. These points should be attended to in the designing of farm-buildings, and the horse-stable and pigsties should be so arranged that the dung and litter may be conveniently spread over fold-yards. Sufficient shed and loose-box accommodation should also be provided; and the open yards must be "troughed," so as to protect the manure from rain, and economise litter as much as possible. By these means straw is saved, and a good quality of manure is obtained. With regard to the staple manure of the farm—that produced by horned cattle—the best is made in loose boxes, or well-protected and small yards, by fatting cattle fed upon cotton or linseed cake, meal, and a few roots.

It was formerly the almost universal custom to cart the dung from the fold-yards, place it in heaps near the field for which it was destined, and to turn it once or twice, so as to promote decay. The advantage of allowing this decay to take place in the land is now so universally allowed that most good farmers prefer to cart a large proportion of their yard manure direct to the fields in the autumn, and there to plough it in. This is a great improvement upon the older practice, especially upon the heavier classes of soils, which derive considerable advantage from the decay of vegetable matter within them.

Farm-yard manure is useful for all crops, and is applied at almost all periods of the year. Immediately after harvest, and throughout autumn, it is carted on to the land intended for the next year's root-crop; in winter it is applied to young seeds; in spring, to potatoes and mangel-wurzel; in summer, to various root-crops, bare fallows, and land intended to be broken up for wheat. The major portion is usually applied to the fallow or root-land; but many good agriculturists prefer to cart a considerable amount on to clover and other leas, in anticipation of wheat. Half the yard manure may be well employed for this purpose, and it will exert the maximum effect when applied to young seeds in the winter or early spring. This secures a good hay-crop, and it has frequently been observed that such a crop is followed by a full crop of wheat. The remainder of the yard manure will be best applied to the root-land from which it is intended to cart the produce to the folds; and the roots which are to be eaten on the ground by sheep may be grown with the help of superphosphates and other artificial manures.

Of late years much attention has been directed to the best method of using straw. It has been shown that this material may be employed for feeding purposes, and that it is too valuable to be employed for litter alone. Accordingly, the greatest economy ought to be observed in using it for this latter purpose, and buildings should be provided to prevent its waste. Some advanced farmers, like Mr. Mechi, have adopted a system of feeding cattle and pigs upon sparred floors, and so have rendered the use of straw as bedding unnecessary. In such cases the excrements of the cattle fall through between the spars which constitute the floor of the sheds or boxes, and are washed, by means of water, to a large tank, from which they are pumped as liquid manure to all parts of the farm. In order to carry out this plan, iron piping and hydrants are required to convey the liquid manure over the land, and also an engine to complete its distribution. Wonderful results have been obtained at Tiptree Hall by the use of such liquid manure, but it is by no means proved that there is any true economy in the conversion of solid excrements into the liquid form. In ordinary farming it is the opinion of most practical men that the best plan is to shut out all extraneous water by properly arranged buildings, and to convert the whole solid and liquid excreta into solid manure by the use of a sufficient amount of litter. Straw need not be exclusively used for this purpose, although it will be long before, even in well-farmed districts, its function as litter ends. Mr. Randell, of Chadbury, recommends burnt clay as a means of absorbing dung and urine, and other agriculturists have employed sawdust, potato-haulm, and other

porous materials obtainable. Another difficulty in finding a better use for straw is the absurd restrictions prevailing in agreements for letting land. The farmer is very often forbidden to sell straw; and should his farm be adapted especially for corn-growing, he has a large surplus of this substance, which he is only too glad to crush into farm-yard manure. So far, therefore, from economising straw, it is not uncommon to find farmers purchasing cattle for the avowed purpose of "crushing down the straw," and this in advanced districts. Landlords would consult their own interests by removing such vexatious restrictions from intelligent tenants, and allowing them to sell the produce of their farms in the best market; and it is absurd that straw, which commands a high market value, should, through a foolish clause in a lease, be trodden into inferior farm-yard manure.

There are other sources of manure upon farms than that of the domestic animals maintained upon it. Every kind of vegetable refuse, such as weeds, hedge-clippings, haulm, leaf-mould, etc., should be collected together and mixed with lime, at the rate of one load of lime to five loads of refuse. The whole should be turned at least twice, and subsequently carted on to the land—not, however, until the roots and seeds of weeds have been killed by contact with lime and sufficient turning. Such a combination of lime and vegetable refuse is what is termed a "compost-heap," and is seen wherever neat farming is carried out.

Farm-yard manure and composts are staple manures; but the requirements of modern agriculture introduce a large class of substances to our notice which, under the names of "hand," "portable," "artificial," and "special" manures, play an important part in rural economy. Volumes might be written upon the composition, uses, and effects of these manures, and it is no easy task to give even a general notion of their application to the numerous soils and crops for which they are specially adapted. The terms *nitrogenous* and *mineral* have been somewhat unphilosophically employed in classifying these fertilisers. The first term requires no explanation. It embraces all manures in which nitrogen plays a conspicuous part, such as many guanos, nitrate of soda, sulphate and other salts of ammonia, blood manure, rape-cake, fish manure, animal refuse of all kinds, etc. "Mineral manures" comprise superphosphate of lime, salts of potash and magnesia, lime, and, in general, substances which supply the fixed or non-volatile parts of plants. Every plant-constituent is essential, but all are not equally abundant. The two elements of plant-life which up to this time have been most in demand are phosphoric acid and nitrogen. Accordingly, phosphatic and nitrogenous manures command a high price, and are very largely employed by farmers. Of late years increased attention has been bestowed upon potash salts, but they are not yet so familiar to agriculturists as the two former classes of manures. Phosphoric acid is supplied in "superphosphates," manufactured from bones or natural mineral phosphates, such as apatite and phosphorite. It is sold at from £5 10s. to £7 per ton, and is applied at the rate of from 3 to 6 cwt. per acre. These phosphatic manures exert the greatest influence upon the root-crops of the farm—*i.e.*, turnips, swedes, and mangel-wurzel; they are also effective upon clovers. Nitrogenous manures are more peculiarly adapted for graminaceous plants, such as the meadow-grasses and the cereals, upon which they exert a most marked effect. Thus the two principal plant-constituents needed as applications to growing crops are added to the land at different periods of the "rotation," and the field is maintained in a fertile condition. Reverse the order, and top-dress wheat with superphosphate, and swedes with nitrate of soda, and the manure in both cases will be all but wasted.

We conclude these remarks upon manuring with a short summary of the manures usually employed, the crops for which they are most suitable, the quantities usually applied, and the season of the year at which they may be used with the greatest effect.

Farm-yard manure, useful for all crops; applied at the rate of from 10 to 30 tons per acre, at various seasons of the year, according to the requirements of each crop.

Rape-dust, *mustard*, *cotton*, and *castor-cake* have all been used, but especially the first. They are rich in nitrogen, and contain valuable "mineral" constituents; they are applied to turnips and cereals with success, and should be distributed during damp weather in spring and summer, at the rate of 5 to 7 cwt. per acre.

Green Manuring, or Manuring with Fresh Vegetable Matter.—Spurry, white mustard, and turnips are employed in this country; and rye, clover, buckwheat, white lupins, rape, borage, etc., have been employed abroad. Sow at the end of harvest, and after two months plough in, as a preparation for winter wheat. It has been recommended to sow and plough in three successive crops of white mustard, as a means of both enriching and cleaning land.

Sea-ware, or *sea-weed*, is washed ashore in vast quantities on some portions of the sea-board, and forms a very valuable dressing for young wheat and grass-land. Its non-fibrous structure allows of a rapid decay, and its large per-centage of nitrogen makes it a valuable manure. It is of greater value per ton than farm-yard dung. This manure is much used in the western counties of England in manuring for potatoes. After having been carted from the sea-side to some convenient spot, it is allowed to lie and rot before it is carried on the ground. The smell of the rotting sea-weed is most offensive; but although it is most unpleasant to the olfactory organs, it is not considered to be unhealthy.

Composts have been already referred to.

Guano, or the excrements of sea-fowl, amassed under favourable conditions for many ages, varies in composition according to the climatical influence under which it has been formed. Peruvian guano is highly nitrogenous, and contains also a large per-centage of phosphates. Guano is applied as a top-dressing to cereals and grasses, and in the north of England and Scotland is largely employed in turnip cultivation. It is applied at the rate of 2 to 4 cwt. per acre as a top-dressing, and in conjunction with superphosphate and farm-yard manure for root-crops.

Hair, *skin*, *horn*, *wool*, *blood*, *fish*, etc., are all employed, either as prepared manures or mixed with earth, and applied as composts. These substances are largely used in the cultivation of hops.

Sulphate and Muriate of Ammonia and Sulpho-muriate of Ammonia.—These highly-nitrogenous manures are peculiarly adapted for grasses and cereals. They may be applied as spring-dressings, at from 1 to 2 cwt. per acre.

Nitrates of Potash and Soda.—The former is rarely used, on account of its high price; the latter is one of the most effective wheat manures we possess. It must be applied in the spring, as it is apt to waste through the soil when subjected to long-continued rains. It should be sown at the rate of from 1 to 2 cwt. per acre.

Common salt is supposed to increase the strength of straw in cereals, and it has a marked effect on mangel-wurzel growing on light soil. The effect of common salt is, however, exceedingly various, and sometimes injurious (Anderson). It may be used at the rate of 5 cwt. per acre.

Salts of Potash, Kainite.—Owing to the discovery of crude potash salts in Germany, potash is now offered at a cheap rate to farmers. Its value is not yet thoroughly appreciated, but it is likely to prove very valuable as a manure for potatoes, clover, and probably other leguminous plants.

Superphosphates, Dissolved Bones, Mineral Superphosphate.—These substances are more generally used than any of the other portable manures. It is by means of superphosphates that the swede and turnip crop is principally raised. These manures are also beneficially applied to grass-land, where they sweeten the herbage rather than increase its bulk. For cereals their use is somewhat doubtful, but they are used for this purpose in combination with nitrate of soda. 3 cwt. per acre is a fair dressing for turnips or swedes; sown with the seed, and either mixed with ashes (burnt soil) or water.

Inch and Half-inch Bones, Bone-dust.—The timid farmer, who fears to trust himself in the hands of the manufacturer, or who is unable to read a chemical analysis, prefers the genuine and visible bone to the impalpable superphosphate. Bones may be at once applied, or dissolved at home by means of sulphuric acid. They form an excellent turnip manure, and half a ton per acre applied to grass-land is a good permanent improvement.

Lime may be applied in the form of marl or chalk, or it may be calcined in a kiln, and distributed over the land as slaked lime. (See our second paper, page 171.)

OBJECT DRAWING.—V.

It will have been observed by the attentive student that the principles which govern object drawing are identical with those which have been explained already in our lessons in "Practical Perspective," and that much which is said in the present series of lessons has been already laid down in detail in that all-important subject, which may well be termed the "grammar of drawing." It must, however, be remembered that the aim of each series of lessons is different, and that in "Object Drawing" the pupil is taught to apply in delineating models and other subjects, truthfully and readily, but without rule and compass, the various rules and processes that he has worked out by the aid of instruments in our lessons in "Practical Perspective."

We now proceed to apply the principles which were laid down in the last lesson.

Fig. 31.—In this example it will be seen that *a b* is the edge of a cube which is nearest to the spectator, and this must therefore be drawn of its proper length.

Now from *a* and *b* draw lines to the horizontal line, which, in this case, is above the object. The vanishing-points will now be outside of the paper.

The cube is supposed to be placed at equal angles; but, as the eye is a little towards the right side of the object, the line *a d* will be longer than *a c*, and thus the right side of the model will be represented as it would actually appear—wider than the left.

Having completed the base of the cube *a c e d*, and raised the perpendiculars *c f* and *d g*, from *f* and *g* draw lines to the opposite vanishing-points, and their intersection will give the distant angle of the upper surface of the cube.

In this quadrilateral draw diagonals, and at their intersection raise a perpendicular. On this mark the height of the pyramid, which will be completed by drawing lines from the apex to the angles of the upper surface of the cube.

Fig. 32.—This is the slab already drawn in a previous lesson (Fig. 24), and will require but little explanation. It stands on edge, its sides being parallel to those of the cube (Fig. 31); and therefore the lines which are horizontal in the model will converge to the vanishing-points belonging to Fig. 31.

It must, of course, be borne in mind that whatever may be the inclination of these surfaces to the picture-plane, so long as the edges are horizontal—that is, *parallel* to the *ground*—their vanishing-points must be on the *horizontal line.*

The student must understand that when the term "horizontal" is used in relation to the *object*, it is meant in a different sense from "horizontal" in the drawing. Thus in Fig. 11 (page 132), the upper and lower edges of the front square of the cube are *horizontal* in the model, and are rendered horizontal in the drawing because the surface is parallel to the picture-plane; but the upper and lower edges of the right-hand side of the cube are horizontal also in the *model;* yet as they are at right angles to the picture-plane they are drawn to the point of sight. Again, the lines *a′ d*, *b′ c*, *b′ e*, and *a′ f* in the model (Fig. 32) under consideration, are all in *reality* horizontal lines; but being inclined to the picture-plane, they converge to the vanishing-points as already shown.

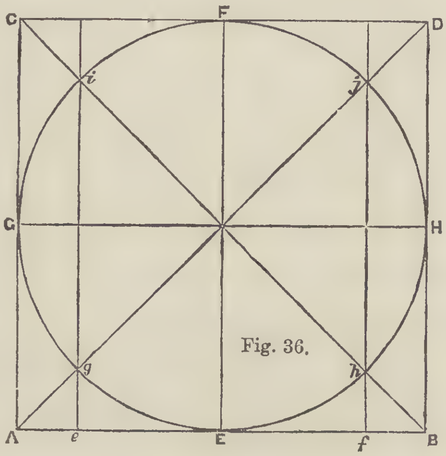


Fig. 36.

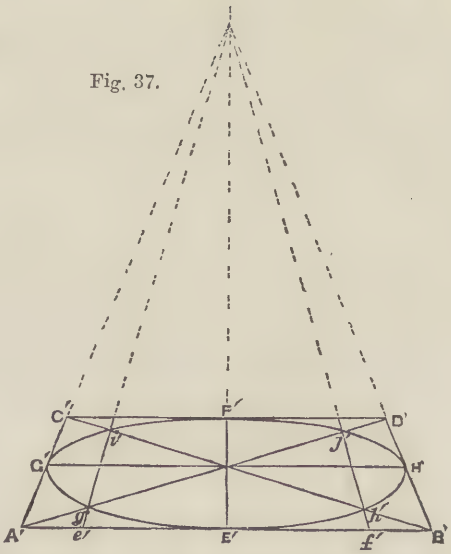


Fig. 37.

Fig. 33 is an equal-sided triangle or prism standing on its end, one of its rectangular faces being parallel to the plane of the picture.

Now it is evident, that if a sheet of glass were placed vertically so as to touch the perpendicular *a b* in Fig. 31, and *a″ b″* in Fig. 33, the sides of the triangular prism would recede from it more suddenly than would those of the cube, because, as shown in Fig. 34, the angle between the face of the cube and the picture-plane would be 45°, whilst in the case of the triangular prism (Fig. 35) it would be 60°.

Therefore the vanishing-points for the triangle will be nearer to the perpendicular than they would be if the object to be represented were a cube. The width of the sides must depend on the position of the spectator; but however much the eye may be moved to the left or right, the points *c d* and *e f* must be on the same horizontal lines so long as the object is placed at equal angles.

The student is urged to remember that the present course of lessons is not by any means intended to supersede, or to be a substitute for, the study of perspective proper. Its object is (1) to give general elementary notions of solid forms to beginners, and by showing them the absolute necessity for really scientific knowledge, lead them on gradually to the more severe studies of projection and perspective; and (2) further, it is hoped, that to those who have already from our previous lessons acquired some knowledge of perspective as a science, the studies herein will afford opportunities for carrying out by the hand and eye alone the principles which they have previously worked out with the assistance of rule and compass, and will suggest to them the method of sketching the thousands of objects which they see around them.

Again and again it is earnestly impressed on all who would really derive from these lessons all the benefit intended, that they *must not merely copy the figures;* but that they should place the models, and draw directly from them; and further, when they have mastered the objects in the prescribed positions, they are advised to change their places and apply the principles which have been laid down.

We now proceed to speak of the method of drawing circles and cylindrical bodies, and must at the onset remark that perspective does not deal with circles or other curves as such, but requires that they should be enclosed in rectangular forms; these are then put into perspective, together with the points in them through which the curve passes. In the case of a circle, the nearest rectangular form which can enclose it is a square; and we will therefore show the method of drawing a circle by this means.

In Fig. 36 is a circle which we require to draw when lying horizontally below the eye of the spectator.

About the circle describe the square A B D C, and in it draw the diagonals A D, B C, and the diameters E F and G H. Now proceed to the sketch (Fig. 37). From A′ and B′ draw lines to the point of sight. Draw the line C′ D′, representing the back of the square. Draw the diagonals A′ D′ and B′ C′, and the diameters E′ F′, G′ H′.

Having proceeded thus far, return to the original figure, and draw the lines *e* and *f* through the points where the circle passes through the diagonals—viz., *g*, *i*, *h*, *j*.

Mark off on Fig. 37, from A′ and B′, the distance A e or B f—viz., A′ e' and B′ f'; and from these points draw lines to the point of sight. These lines, passing through the diagonals, give the points g', i', h', j'.

Eight points are thus obtained—viz., E′, g', G′, i', F′, j', H′, and h'. Through these the curve which is the perspective representation is to be drawn.

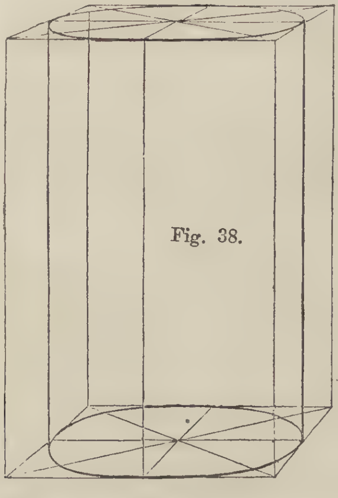
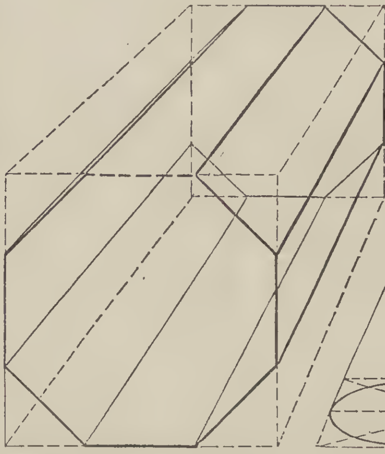


Fig. 38.

Fig. 39.



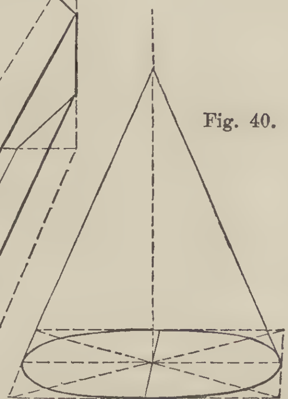


Fig. 40.

Now, as the *circle* just drawn is shown to be described in a plane *square*, it is clear that a *cylinder* would be contained in an oblong *block*, the ends of which are *squares*.

Proceed, therefore, to sketch such a block (Fig. 38), and, guided by the knowledge of the principles laid down in Figs. 36, 37, draw the elliptical figures representing the upper and lower ends.

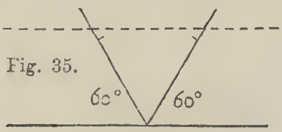


Fig. 35.

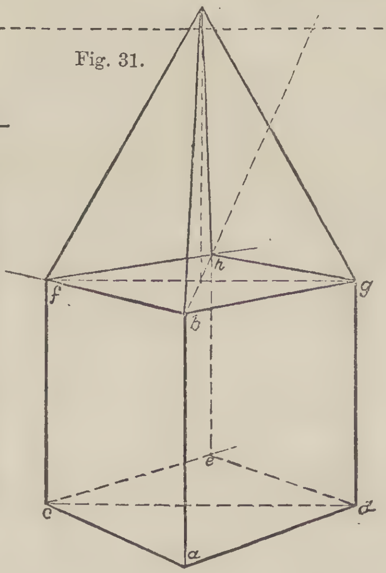


Fig. 31.

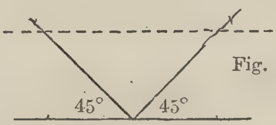


Fig. 34.

Fig. 33.

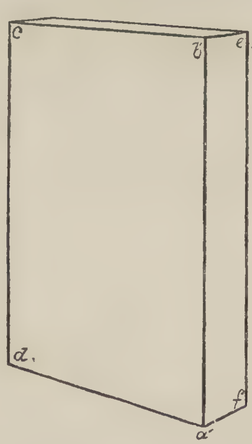


Fig. 32.

Great care must be taken in drawing the perpendiculars; they must join the curve in a smooth manner, so that no sharp point of junction is visible, and yet the object must not appear as if it were rounded off at the bottom, which gives a cylinder an unsafe or sack-like appearance, and makes it look as if it would not stand upright.

It is needless to say that a cylinder placed horizontally would be drawn in a similar method; the position of the oblong being changed according to that of the cylinder.

Fig. 39.—This is an octagonal prism. The end of the prism is parallel to the picture, and therefore retains its geometrical shape. Various methods for constructing polygons are given in lessons in "Practical Geometry applied to Linear Drawing," and it is assumed that the student has already acquired this knowledge; if not, he is urgently advised to commence the study at once, as it is the basis of all other useful drawing.

The figures in the present study are not, however, intended to be constructed geometrically, but the knowledge of the principles will materially aid in the rapid and correct delineation.

Having, then, drawn the octagonal end, draw lines from the angles to the point of sight; and it will be remembered that the distant end, since it is parallel to the near one, retains its regular shape so that no further instruction will be necessary to complete this object.

Fig. 40 is a perspective view of a cone. Having drawn the figure containing the base, draw diameters, diagonals, etc., and raise a perpendicular from the intersection.

Trace the curve in the quadrilateral, and draw the lines for the surface of the cone.

It is needless to say that these straight lines, enclosing curved forms, are only to be used as guides in the early stages of study; but a very little practice will soon enable the student to sketch the required form at once, using merely a horizontal for the diameter.

THE ELECTRIC TELEGRAPH.—XII.

By J. M. Wigner, B.A.

HOUSE'S PRINTING TELEGRAPH—HUGHES'S INSTRUMENT—INSTRUMENTS USED AT PRESENT TIME IN THIS COUNTRY—ARRANGEMENTS AT CENTRAL OFFICE—CONCLUSION.

The alphabetical or universal telegraph we have just described is admirably adapted for use on private lines, and has been extensively adopted. For ordinary telegraphic purposes, however, it is far inferior to the single-needle and Morse instruments, as a less degree of speed is attainable by it; and, at the same time, its more complicated construction renders it more expensive and liable to get out of repair. The electric current, too, is produced by induction from a permanent magnet, and is therefore too weak to be used on long lines.

Many attempts have been made to produce an instrument that should print its messages in ordinary printing characters, so that the strip itself as received might be sent out of the office without the labour and risk of transcribing. In Bonelli's printing telegraph, already described, this is accomplished; but, as we saw, five line-wires are required instead of one, and the instrument is thus rendered of little practical value. Several others have been devised to attain the same end with one wire. In most of these the letters of the alphabet and other signs are engraved round the edge of a steel type-wheel, which is made to revolve by clockwork, and the motion of which is controlled by means of a scape-wheel and an electro-magnet, somewhat in the same manner as in Breguet's instrument, described in our last paper.

This type-wheel revolves against an inked roller, and is made to stop when the letter to be printed is opposite the paper strip. The strip is then, by means of suitable mechanism, pressed against the inked type, and thus the letter is printed. As the strip recedes from the type, it is drawn forward a short distance, so as to be ready to receive the next letter. One blank space is left in the type-wheel, and this leaves a blank on the paper. By sending this an interval is left between the different words of the message.

An instrument of this kind, invented by a Mr. House, of New York, was extensively adopted on many American lines. The contact-wheel by which the currents were sent was divided into twenty-eight spaces, for the twenty-six letters, the full stop, and the +, which left a blank on the recording strip. Each alternate space was then cut away, so that it really became a wheel with fourteen teeth. A spring was pressed against these, so that the contact was alternately made and broken at each letter. On the axis of this wheel was placed a cylinder, with twenty-eight pegs fixed at equal distances in a spiral line round it.

The letters were engraved on the notes of a key-board, somewhat resembling that of an ordinary piano; and when any one was pressed down it raised a cam, which caught against the pin on the cylinder corresponding to its letter, and thus arrested its motion at the right moment. In the receiving instrument the paper was pressed against the type by a mechanical arrangement, and not by an electro-magnet, as is done in most similar instruments.

Hughes's printing telegraph is a very great improvement on this instrument, and is now in constant use on many important lines, both in England and abroad. It is the only instrument which prints its messages in ordinary type that is now employed by the Postal Telegraph Department in this country.

The principle on which it acts is to ensure the synchronous movement of an inked type-wheel at each station. In this there is, of course, great practical difficulty; but it has been fully overcome, and though the type-wheels make 120 revolutions a minute, they keep time with the greatest accuracy.

The regulator employed for attaining this uniformity of motion consists of a spiral vibrating spring, firmly fixed at one end. The type-wheels are set in motion by a heavy weight and a train of clockwork. A small fly-wheel driven by this is connected to the free end of the vibrating spring, so that the greater the motive power the greater will be the arc of vibration, but its rate will remain uniform. In order to adjust it accurately, a small sliding weight is placed on the spring, and this can easily be moved and clamped at any required place. This spring, therefore, acts in the same way as the pendulum in an ordinary clock, and is capable of as delicate adjustment.

Even with this, however, the type-wheel might be very slightly out of position, and thus would not print the letter clearly. A wheel with wedge-shaped teeth, known as a "corrector," is therefore mounted on the same axis as the type-wheel; and just before any letter is printed, a wedge-shaped cam strikes between the teeth of this, and forces it into its exact position. This correction takes place at every letter that is printed.

The construction of the whole apparatus is far too complicated to allow of the details being explained in the short space at our disposal, and almost any description would require an instrument by the side to render it perfectly clear. Its plan of working may, however, be easily understood.

The letters and signs are engraved on a key-board similar to that employed in House's instrument; two letters are, however, placed on each key, and there are two blanks. Either sign may then be sent at pleasure, according to which blank we depress. In this way fifty-four different characters, consisting of the letters, numerals, and various signs, are sent with twenty-eight keys. On the type-wheel the letters and figures are placed alternately, and by a suitable arrangement either can be printed at pleasure.

In the centre of the instrument is a horizontal brass disc, with a number of radial slots cut near the circumference. These correspond to the signs on the key-board, and as any key is depressed a pin connected to it by means of a lever is raised through the corresponding slot. Above this disc is a vertical shaft, revolving simultaneously with the type-wheel, and carrying a contact-making arm. As this revolves it comes in contact with any pin that is raised, and immediately causes a current to pass along the line-wire. This current sets free the printing-gear at each station, and thus causes the required letter to be printed. The keys corresponding to the successive letters of the message are then pressed down, and these are in like manner printed. In the type-wheel is a blank corresponding to one of the blank keys; this is sent at the end of each word, and leaves a space between it and the next. In this way the message is transmitted at a considerable speed, it being found that thirty or forty messages per hour may easily be sent by the instrument.

The electro-magnet which sets free the printing-gear is of peculiar construction. As the type-wheel revolves very rapidly, it is important that the paper should be brought into contact with it and again withdrawn as quickly as possible. A permanent horseshoe magnet is therefore employed, and has soft iron poles fitted to it, and wound round with fine wire. A spring on the armature tends to keep it away from the poles of the magnet. The tension of this is capable of adjustment by means of a screw, and it is so arranged that when the armature is against the poles the permanent magnetism is just sufficient to maintain it there despite the resistance of the spring. As soon, however, as the current travels round the coils, this permanent magnetism is reversed, and the keeper instantly flies away. In doing this it unlocks the printing-shaft, and allows the strip of paper to be rapidly pressed against the type-wheel and again withdrawn. By this latter movement the keeper is brought back again to the poles, and retained there till liberated by a fresh current.

The printing-gear is so arranged that at each letter printed the paper is drawn forward a short distance, so as to be ready to receive the next letter.

The strip of paper printed in this instrument is cut up, gummed to one of the ordinary message-forms, and sent out. No record is thus retained in the receiving-office, but this is not of much importance, as the message is printed simultaneously at the office from which it was sent, and the strip there is carefully preserved, should there be any need to refer to it afterwards. Before commencing work each morning a few blanks are sent, that is, the same key is pressed down several times in succession. If these print the same letter at each end, the vibrating springs are correctly adjusted; if not, they must be altered, and then all is ready to commence work. In order to start the type-wheels simultaneously, a catch is provided, and by pressing on this they can only start from the blank.

We have now hastily described all the chief forms of telegraph that have come at all into use, and it is hoped the student has acquired such a clear insight into their action that he will easily understand the principle of any other instrument he may

meet with. Only a few of these various instruments are, however, in actual work in this country at the present time; some others were for a time worked by different private companies, but have been discontinued since the various lines were taken over by the Government.

A short account of the instruments in use at the Central Telegraph Office in Moorgate Street, London, will give a good idea of the state of the telegraph system in England at the present time, and thus serve well to bring these papers to a close.

In this office there are several hundred instruments of various kinds constantly at work, the electricity required being generated in batteries which are placed in cellars beneath the building. The wires from these are led to the different instruments as required, under the various floors of the building.

One portion of the building is called the Metropolitan Gallery, and is set apart for messages to and from various parts of London; a separate division is used for provincial messages.

Desks or counters are placed across these rooms from side to side, and along these, at distances of a few feet, are placed the various instruments, nearly all of which are worked by young women. In front of each sits the clerk, with a supply of forms for writing the messages on placed in front of her; and over most of the instruments in the provincial gallery is placed a label showing the town with which they are in communication.

By far the greater number of instruments are the ordinary single-needle and the Morse recorder, which have already been described. Nearly all of the single-needle instruments are, however, now worked with a double tappet, similar to that described and figured in Vol. I., page 401, instead of with the barrel commutator previously described, this being now almost entirely confined to double-needle instruments.

The commutator is usually fixed in the same case as the coil, so that the two tappets or finger-plates project from it in place of the handle. The instruments made in this way are cheaper and less liable to get out of repair, though many of the clerks prefer the older form.

Morse instruments of every kind are also to be seen. In what might be called the standard form, the key, recorder, and galvanometer are placed on the same stand; but there is a very great diversity in the form given to the different instruments. All, however, act in the same way, as has been fully explained.

A few of Wheatstone's automatic instruments, somewhat modified, may also be seen in one of the rooms. In these the paper strip is punched in a somewhat different way from that already described, the object of the alteration being to allow the ordinary Morse recorder to be used either with the key or the punched strip. The punching apparatus is so arranged that at each blow on the anvil two holes are punched, one at each edge of the strip. When a dot is to be sent, these holes are placed directly under one another, thus $\overset{\circ}{\circ}$, while a dash is denoted by two placed in this manner, $^{\circ}{}_{\circ}$; and the transmitting apparatus is so arranged that these cause one current of longer duration to be sent, and so print a dash at the receiving station. A middle row of holes is punched along the paper at the same time to space the words. The word "Morse," as punched in this way, is here shown (Fig. 56), the equivalent dots and dashes being placed under the various characters.

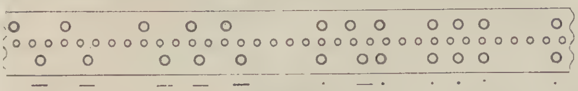


Fig. 56.

In the same room is one desk at which a number of the Hughes' printing telegraph just described may be seen at work, and these constitute one of the most interesting features of the office.

In addition to these instruments, there are a few of the American "sounders," which have been introduced very recently, and one or two specimens of Bright's bell instrument. Speaking roughly, however, we may safely say that the two instruments employed are the single-needle and the Morse.

Between large and important towns through wires are usually provided, so that messages are sent direct from one to the other; but in a large number of cases the message has to be received at one instrument and re-transmitted along another line. The wires might be put in direct communication by means of switches, but in practice it is found far more rapid to receive and re-transmit the message. Sometimes a message has thus to be telegraphed several times before reaching its destination.

To save the great trouble and loss of time which would be caused by carrying these messages from one part to another of the building, a series of endless tapes were recently fitted in the office. These pass round rollers kept in constant motion, and the message, being placed between them, is at once conveyed from the Metropolitan to the Provincial Gallery, or *vice versa*.

Between some City stations, and between this office and the General Post Office, there are so many messages constantly passing that several wires would be required. Pneumatic tubes have therefore been laid down, and the message, written in the ordinary form, is rolled up, inserted in a carrier made to fit these, and propelled along them to the required station, where it falls out of the tube on to a tray placed to receive it. A vacuum is produced in these tubes by steam-power, and the carrier is sucked one way and propelled the other.

A larger tube has now been laid down between Moorgate Street and the office in the West Strand, calling at Temple Bar on the way, and many messages are constantly being transmitted along this. The plan seems, indeed, to answer so well that it will probably be extended to other important stations.

We have thus completed our survey of the English telegraph system, and have seen some of the results that have accrued from the simple discovery made by Galvani.

Had any one ventured half a century ago to predict that our messages would be flashed at lightning speed to distant continents, and answers received in the space of a few minutes, he would have been deemed mad; but even this has now been far exceeded. In scarcely any other branch of science has such rapid progress been made, and we are still hearing of fresh discoveries; though there has been but little change in the instruments employed during the last few years.

COLOUR.—XII.

By Professor CHURCH, Royal Agricultural College, Cirencester.

COLOURED GLASS—COLOURS OF POTTERY AND PORCELAIN—MINERAL PIGMENTS—COLOURS OF PLANTS, FLOWERS, WOODS, AND VEGETABLE FIBRES—COLOURS OF ANIMALS AND ANIMAL PRODUCTS.

WE have now to consider the peculiarities of coloured glass. Glass, being a vitreous and not a crystallised substance, does not present that extensive variety of optical properties which characterises many natural gems. It is probably on this account that the most perfect and uniform coloured glass is not by any means satisfactory or interesting from an artistic point of view. Very instructive examples of the bad effect of such glass are to be seen in many painted glass windows, especially in those which belong to the earlier period of the recent revival of Gothic art in this country. The blue and other glass is deep enough in colour, but lacks real richness; it is thin and flat, though staring. There is no fluctuation of colour, no breaking up and scattering of the transmitted beams of light. The glass to accomplish this must be less perfect as a mechanical product of manufacture. If the colour be uniformly diffused throughout the glass, the glass must vary in thickness, its surfaces must be uneven; and striæ and blebs only improve the effect. A glass which is absolutely perfect as glass may be rightly devoted to the construction of optical instruments, but is incapable of completely realising the poetry of colour.

The colours of glass may arise from several causes. A fine white powder—say oxide of tin—diffused through clear glass gives it the opalescence of a cloudy medium; a bluish colour being produced by reflected light, and a yellow or red colour by transmitted light. Opal glass may vary from a faint cloudiness to milky and nearly opaque white. Another glass, owing its peculiarity to solid matter, is known as aventurine glass; it contains glistening crystals of copper. But the colours of most transparent glasses are due to the presence of metallic silicates, such as those of iron, copper, cobalt, and manganese. These metals give to glass various tints of green, orange, blue, and violet. One metal, uranium, imparts not only a distinct yellow colour, but the interesting property called fluorescence. The common "canary" glass is a glass of this kind. Viewed by transmitted light it is yellow; but when the solar beams fall

upon this kind of glass, the actinic rays are modified, and are reflected back to the eye as green light.

The method of using coloured glass in windows should be limited very strictly by the nature of the material, as well as by the office of a window. The glass must not pretend to be a picture, nor must it contain large shaded or obscured portions, opaque or nearly so to light. Minute lines and details of drawing are out of place and useless. A mosaic work of small pieces of glass, separated by bold and firm lead lines, is most effective. If the window is required to let in unmodified daylight, the glass may be decorated with firmly-drawn outlines in dark maroon or brown upon a white or grey ground, the pattern extending through a large number of quarries. Here and there a medallion of richer colour may be symmetrically introduced. Where highly-coloured windows are considered desirable, some of the richest and happiest effects are to be obtained by the use of blue glass in preponderating quantity, as in the ancient glass of Canterbury Cathedral, or of ruby-red with blue, as in the windows of La Sainte Chapelle, at Paris. Some portions of the latter glass may be studied at South Kensington. Where the pieces of glass are small, the effect of the contiguous beams of red and blue light is to produce a result similar to that of violet glass, but infinitely richer, more brilliant, and more "bloomy;" while the lead lines prevent a confused mingling of the colours when seen more closely. Mosaic work in coloured glass is most appropriate and effective. Painting in *chiaro-oscuro*, especially in monochrome, is radically bad in theory, and unpleasant, to say the least, in result.

The peculiarity of the colours of porcelain and pottery consists mainly in the mode in which they are applied to the wares. In the case of delft, faience, and majolica ware, the colours are painted, as enamel colours, upon an opaque white or nearly white stanniferous enamel. Transparent or translucent colours on this opaque ground come out with great force; while opaque colours appear less characteristic than they do upon porcelain, and upon translucent bodies generally. Upon earthenware and porcelain, designs may be either printed or painted, either under or over the glaze. Colours printed or painted over the glaze are generally better defined and more brilliant than those which are below it. In the decoration of pottery and porcelain, besides the use of enamel colours, other decorative effects may be produced by means of preparations of gold and platinum, and by means of colours mixed with the body of the ware or the glaze. Some of the most remarkable effects of the latter sort are to be seen upon the old Italian lûstre-ware plates, and upon the modern porcelain of M. Brianchon, imitated at Worcester and Belleek, in which cases the iridescent glaze contains a considerable amount of bismuth in its composition.

A very important series of coloured materials is produced directly or indirectly from minerals. Most of the native mineral pigments are of a useful and permanent character. The compounds of iron, chiefly oxides and hydrates, have always been largely employed in the arts, and afford a wide range of useful colours—yellows, reds, browns, maroons, etc. The colours derived from copper, such as verdigris and malachite, are more liable to change by conversion into the black oxide and dark brown sulphide of this metal. Pigments made out of coloured glass or frit—such pigments, for instance, as smalt and ultramarine—are commonly difficult to manipulate and mix, but yet are endowed with considerable fixity. Preparations of lead, such as the carbonate and the chromate, white lead, and chrome yellow respectively, are subject to one great drawback. This is their sensitiveness to sulphuretted hydrogen, which darkens and destroys all the more delicately-coloured preparations containing this metal with considerable rapidity. The protection of these materials from change is partially effected by covering the particles of which they consist by a film of oil-varnish, wax, paraffin, or gum, as in the ordinary methods of painting in oil, encaustic, or water. In fresco and distemper painting, where lime or size serve to bind or cover the pigmentary granules, the action of injurious substances upon sensitive materials is more rapid. In stereochromy, and other methods of silicious painting, the colours are less liable to change. But then the range of colours is rather limited, owing to another consideration—water, glass, and the alkaline silicates in general, which constitute the medium with which the pigments are mixed in stereochromy, or with which they are fixed, alter and destroy many mineral colours, such as emerald green, Prussian blue, and chrome yellow. If we exclude such alterable pigments, including most preparations of lead and copper, and then further eliminate, for the same reason, some of the most beautiful vegetable and animal colouring matters, the residue of available pigments is indeed small. The point, however, to which we now wish to draw attention is not the modification of colour by injurious atmospheric or other influences, but the colour-peculiarities caused by the nature of the medium with which the pigments are incorporated, or by the optical qualities of the pigment itself. The most important general characters of pigments reside in their translucency, or opacity, as regards light. A transparent pigment need be much less saturated or intense to produce a given colour-effect than an opaque one. The reason of this will be clear when the statements made in former lessons are recalled. The light reflected from the ground on which a transparent colour is laid has to pass *twice* through that colour; while an opaque colour often reflects, or at least scatters, much unaltered white light. The use of clear colours upon opaque grounds or painted surfaces is often called glazing by artists, and gives a depth, intensity, and richness which cannot be exactly attained in other ways. *Scumbling* is the precise opposite of this, for in it an opaque colour or white, mixed with some oil or other medium, is used to cover partially, and so to modify, the clear or mixed colours which have been previously laid on. It conveys an idea of distance, or mystery, or cloudiness.

The binding material which unites the particles of a pigment together, or which retains them on the painted surface, may be either opaque or transparent. In all ordinary water-colour and oil-colour painting, the binding material is practically transparent; but in fresco painting it would seem that the freshly-covered surface acquires a film of carbonate of lime (calcium carbonate), which gives deadness and opacity to the surface of pictures executed by this method. Something of the same kind of effect is produced in the several methods of silicious painting, of which the only one which is of any importance, and has been practically employed, is the stereochromy of Fuchs In this process the pigments are bound to the wall, and acquire coherence by the changes which the soluble potassium and sodium silicates used in the process undergo. They appear to enter into direct combination with the zinc oxide or calcium carbonate laid on as a ground or mixed with the pigment. The silicate must not be saturated with silica, but should be, contrary to the usual opinion, strongly alkaline; otherwise an irremovable silicious bloom will shortly disfigure the mural painting executed by this process. The wall, slate, plaster, or stone to be decorated should be wetted with baryta-water, painted with the previously-tested colours, and then, when dry, syringed with a fine spray of the fixing silicious solution. This syringing is repeated at short intervals, until no trace of colour can be removed with a dry or wet hard brush applied to the painting. If a saline bloom appear after a time, it should be removed by means of sponging with distilled water. If a hard white silicious bloom mar the brilliancy of the colours, no chemical or mechanical method is competent to remove it. But in this case the appearance of the injured fresco or stereochrome picture may be greatly improved by a process which the writer of these lessons invented in 1856. It consists in the use of paraffin, driven into the picture by heat, or applied in the form of solution, by a brush or in spray. The solvent used may be either benzole or mineral turpentine. Some fine copal or dammar varnish is a desirable addition to the solution. In this way old distemper paintings may be preserved from destruction. The effects of damp and decay are arrested, and the colours may actually acquire more than their pristine beauty. In fact, this process converts the opaque binding materials of the painting into transparent or translucent ones. It is scarcely necessary to say that all colours, oils, and varnishes should be tested before they are used, if their colours and appearances are to remain unchanged. No soluble saline matters should remain in pigments; they ought to be tried alone and mixed with others, to see if they alter or fade when exposed to sunlight. The oils and varnishes must be examined to see whether they darken, or if they irregularly contract on drying, and so forth. But we must not dwell further on the chemistry of pigments, of grounds, and of the

media and methods of painting, for this subject requires a volume for its adequate treatment. Yet we must add a word or two on a subject of the utmost importance to artists, and to those who are engaged in copying pictures. As the colours which we see are modified subjectively, it is necessary that they should not be reproduced as we see them, but as they actually exist. The high lights of a blue robe may appear yellow or orange to us, and yet could be copied only by the use of a lighter tone of blue. So the high lights of a face may give by way of contrast a greenish hue to its shaded parts, although this effect would not be reproduced, but grossly exaggerated, by mixing some green with the grey of these parts.

The most conspicuous colours belonging to flowers are usually very fleeting, and cannot be utilised for decorative purposes. Generally, too, they are particularly liable to alteration by acids or alkalies—becoming red under the influence of the former agents, and blue or green by the action of the latter. This property has been turned to account in chemical testing; one of the best test-papers being prepared from that beautiful crimson-foliaged plant, the *Coleus Vershaffeltii*. The stems of the plant are bruised and extracted with spirit; then white blotting-paper is soaked in the solution. The lavender-grey of this paper becomes red with acids, and green with soda and other alkalies. In the copper-beech and the dark portions of some zonal geraniums, we have the ordinary green colouring matter of leaves, called chlorophyll, mixed with a crimson colouring matter, the combination producing a kind of deep maroon. The extreme beauty of the colours of many flowers depends in part upon their peculiarities of structure. The cell-walls within which the vegetable pigments occur are often extremely thin, and present a soft yet glistening aspect, which enhances and varies the colour-effects of their contents. This aspect, though often called crystalline, in no degree arises from any structure to which this term can be applied. Some very beautiful and yet permanent colouring matters are, however, obtained from plants, though these do not always contain them ready-formed. As instances in point, we may cite indigo and some of the madder colours.

The vegetable fibrous materials used in the manufacture of textile fabrics are generally white or pale yellow, but may be dyed of any colour by suitable processes. In some cases the dyeing material may be made to enter a central cavity in the fibre; but usually colouring substances can be made to adhere permanently to vegetable fibres only by means of a mordant. First of all, a substance such as tin peroxide, having an attraction for colouring matter, is precipitated upon the fibre, and then it is immersed in a dye-bath. The colouring matter is withdrawn from the liquid, and adheres firmly to the mordanted fibre. The lustre of vegetable fibres is usually not very marked, and is diminished in the process of dyeing them. Linen, the woven fibres of flax, does, however, reflect the light which falls upon it with considerable power, particularly in certain positions. A pattern may thus be made in which the strands which form the warp may be contrasted, not only as regards colour, but as regards lustre, with those of the woof. Under these conditions damasked linen, just like silk damask, may exhibit a curious optical illusion. If a white warp and a red woof be associated, it will be noticed that in certain lights the white parts of the fabric assume a bluish-green tint, acquiring, very distinctly, the tint complementary to the dyed threads, the effect being enhanced by the difference of lustre dependent upon the way in which the light falls upon the fabric. Similar but still more decided effects are seen in fabrics in which lustrous silk and dull cotton or wool are associated. Nor should we here neglect to allude to the peculiar mingled tones produced by the repeated recurrence at short intervals of similarly coloured strands in a fabric.

The colours of woods are usually subdued, but varied. Much of the beauty of some woods depends, however, rather upon texture and lustre than upon colour. In furniture, and the general decorative treatment of wooden construction, much may be made out of the combined use of these two qualities of lustre and colour. One wood dark, and of lustrous texture, may be introduced in the form of bosses, panels, or mouldings into a framework of an opaque and light wood. So woods of distinct patterns may be associated with those which possess an uniform appearance. The colours of woods are, indeed, brought out by varnishing and oiling; but the former of these processes has a tendency to check those alterations of tint which often render old specimens of woodwork far more beautiful than new.

The colours of animal products are usually less changeable than those of vegetable products. In some cases, notably in the case of the humming-birds, the brilliant, almost metallic, colours of the animals are due rather to the optical structure of the coloured substance and surface than to any actual colouring matter. Instances, however, do occur, as in the plaintain-eaters, or touracous of Africa, where a colouring matter may be actually extracted from the brilliant plumage of birds. The colouring matter of these birds was discovered by the present writer, and found to resemble the red colouring matter of arterial blood (*cruorin*) in some respects. It is especially remarkable as containing a fixed per-centage of the metal copper. White feathers, like other animal products, may be dyed without any mordant, silk and wool being particularly characteristic examples of this fact; ivory, bone, and horn may be noticed in the same connection.

If our treatment of the subject of colour has sometimes seemed to our readers to have been destitute of practical value, we yet trust that the principles laid down will serve to furnish a guide, at once effective and safe, in the arrangement and study of coloured compositions, both pictorial and decorative. Further information may be gained, both as to textile fabrics and paintings, from "The Laws of the Contrast of Colour," by M. Chevreul; while Dr. E. Brücke's treatise on "Colours," which may be read in the French translation of Dr. Schutzenberger, enters more fully into the physical and physiological matters connected with this subject. Besides the papers of the late Dr. George Wilson, of Helmholtz, and of Professor Clerk Maxwell, we have two excellent works from the pen of Mr. W. Benson. These latter are entitled respectively, the "Principles of the Science of Colour," and a "Manual of Colour," and deserve careful study. Nearly all these works contain something about the singular condition, to which we have been able to allude but cursorily, known as Daltonism, or colour-blindness. A nomenclature of colours, unfortunately imperfect, will be found in Brooke and Miller's "Manual of Mineralogy;" but it is greatly to be desired that the names used to indicate the most important varieties of colour should be applied in a more definite manner.

SANITARY ENGINEERING.—V.

SUNBURNERS.

In some previous papers, having for their subject "Gas" in its various phases of use—as a manufacture, as an economical means of lighting, etc.—we have given technical details bearing upon different aspects of the subject. The question before us—the use of sunburners—has special reference to the lighting of large public buildings, theatres, churches, manufactories, or any large room, where the cost of the light is not so much an object as that there should be a good diffused general light, and plenty of it, and that this result should be obtained without interfering with the ventilation, or, in other words, that the products of combustion, the carbonic acid gas and other fumes which produce the closeness in all large gas-lighted spaces of which we now so constantly complain, should be efficiently removed; and this result is surely and efficiently attained by the adoption of the "sunburner."

In some of our previous papers economy in consumption has been the point in view. In this case that has to a certain extent to be disregarded, a thoroughly good light, combined with efficient ventilation, being the object sought after in all public undertakings, the mere cost of gas burnt being a somewhat secondary consideration under the circumstances.

The burner consists of a number or group of union jet burners, commonly called fish-tails, arranged in the form of a circle or a star, larger or smaller according to circumstances, but so placed as to throw out their flame horizontally and not vertically, the draught of air being regulated accordingly. These were originally, on the first introduction of this method of lighting, placed under a funnel made of sheet iron with a short pipe rising from it, which was encased by a larger funnel, from which a pipe, acting as the flue of the sunburner, was taken by the most convenient route to a communication with the external air.

When first used these funnels, being made throughout of iron, threw up on to the ceiling a very dense shadow, which, when it

was necessary to fix the sunburner, as is sometimes the case, at some distance below, interfered very much with the architectural decorative effect of the room. This difficulty has been overcome by perforating these casings throughout their surface with a series of openings, and filling the openings thus made with sheets of mica, thus allowing the light to be distributed while confining the air. The great heat always generated by the light produces a strong up draught, not only removing the products of combustion, but creating in the space between the inner and outer shaft a current which keeps up a constant drain upon the heated air in the upper portion of the room.

In the earlier stages of the invention it was found, however, that when the gas was not lighted a strong down draught of cold air constantly passed down the pipe. A valve was then provided in the inner tube to control the draught, which, in the first instance, was moved by hand—opened at night when the gas was lighted, and shut when it was turned off. There was, however, this risk, which was a serious one: if by any accident the valve was left shut after the gas was turned on, the portion of air below it gradually became mixed with gas, until the mixture acquired that character well known as a highly explosive compound, and from which all the gas explosions of which we are constantly hearing arise.

Finally, a self-acting valve was invented, acting by the pressure of the gas in the supply-tubes on inverted vessels floating in mercury. When the gas is turned on this opens the valve, and when turned off it shuts it. All risk of explosion is thus avoided, and down draught effectually cut off. For obtaining a large body of fixed light in any given situation the sunburner, with these improvements, is undoubtedly one of the best, if not the best, means at our command.

In introducing the sunburner, however, the risk of fire has always to be provided against, as the heat generated is so great. In London the Building Act requires a space of nine inches between the flue and any combustible material; but this is more than is absolutely requisite, as half that space is sufficient for safety; and in the North it is not uncommon to have three or more wrought-iron tubes enclosing each other, each with air-space between, this forming a perfectly efficient protection.

The fittings of the burners should be adapted to the architectural character of the interior where they are used, and this is a point that has been carefully studied by different manufacturers, so that either a classical, or Gothic, or other character has been given to the decorations required either around the rim of the funnel surmounting the burners, or over the general surface of the tubes where visible. There are also many artistic designs for the adaptation of glass lustres to sunburners, which may thus be rendered equal in effect to the most elegant chandeliers or pendants, suitable either for the drawing-room, the ball-room, or the theatre. For ordinary household purposes—*i.e.*, for small rooms anything less than twelve feet high—we do not recommend the introduction of this method of lighting, as the great heat generated in the flues, which have to be conducted through the narrow space between floor and ceiling, has a marked effect both upon the timbers of the floor and the atmosphere of the room above, and the light required can be more economically and efficiently attained by a different arrangement of the burners; but for large public buildings where an audience has to be accommodated, or in large reception-rooms which have the necessary elevation, good light combined with efficient ventilation can be more readily obtained by this adaptation of gas-lighting than by any other.

For billiard-rooms, where sectional height permits its introduction, it has been found successful, and we may mention one or two public buildings where it has been adopted, we understand, with the most satisfactory results. The Gaiety Theatre is one of them, the well-known public room at Evans's another; here are a series of sunburners architecturally arranged so as to form centres in the various panels of the ceiling, which is highly decorated with gilding, colour, and figure-painting. Again, in the "shop," as it is professionally termed, of the Bank of England, at the corner of Threadneedle Street, a series of pendentives are arranged; the ceiling is groined, circular, and of high architectural pretensions; and the termination of each pendentive forms a very fitting position for the introduction of the sunburner, which is fixed at that point.

When provision is made in the erection of a new building for the introduction of this method of lighting, the cost will scarcely exceed that required for any other method, as the requisite fittings need not be more expensive than those ordinarily in use for other arrangements for lighting; and by a well-considered arrangement of flues the up draught of the sunburner may be made, in its general action, to assist the ordinary ventilating flues.

When a building already erected has to be thus lighted, of course care is required in the detail of construction to avoid risk of fire; but that once duly provided for we may safely say that for large rooms for public purposes the sunburner is the most efficient appliance of the day.

NOTABLE INVENTIONS AND INVENTORS.

XVII.—THE DIVING-BELL.

BY JOHN TIMBS.

The contrivance of apparatus for enabling men to dive, or descend beneath the surface of water, to a greater depth, for a longer space of time, and with less exertion and danger, than is possible by the unassisted power of the body, long exercised the ingenuity of mankind in past ages. About half a minute is the longest period during which most individuals can safely remain under water—in fact, can *live under water*—without some provision for the supply of air for respiration. Experienced divers have never, with few exceptions, remained under water more than two minutes; and although exaggerated statements are given of divers remaining for hours under water, six minutes is about the longest time of submersion of which any trustworthy account has appeared in modern times.

The sponge-divers in the Archipelago take down in their mouths a piece of sponge soaked in oil, as a means for assisting the diver to see when under water. In still water, light is frequently transmitted to a great depth; but when the surface is disturbed by waves, it is much obstructed. To ensure a good light, which may enable the diver to find objects of his search without delay, it is stated that he ejects a little oil from the sponge, and this oil rising to the surface, and spreading upon it, calms the waves in a most remarkable manner, and occasions a brilliant light at the bottom.

Among the earliest plans is that mentioned by Aristotle, who is supposed to intimate that in his time divers used a kind of kettle to enable them to continue longer under water; but Beckmann places little reliance upon this statement. He adds, that the oldest information we have of the use of the diving-bell in Europe is that of John Taisner, quoted by Schott, in his "Technica Curiosa," Nuremberg, 1664, in which Taisner relates: "Were the ignorant vulgar told that one could descend to the bottom of the Rhine, in the midst of the water, without wetting one's clothes, or any part of one's body, and even carry a lighted candle to the bottom of the water, they would consider it altogether as ridiculous as impossible. This, however, I saw done at Toledo, in Spain, in the year 1538, before the Emperor Charles V., and almost ten thousand spectators. The experiment was made by two Greeks, who, taking a very large kettle suspended by ropes with the mouth downwards, fixed beams and planks in the middle of its concavity, upon which they placed themselves, together with a candle. The kettle was equipoised by lead fixed round its mouth, so that, when let down towards the water, no part of its circumference should touch the water sooner than another, else the water might easily have overcome the air included in it, and have converted it into moist vapour; but if the vessel were gently drawn up, the men continue dry, and the candle is found burning." Schott calls the machine described an "aquatic kettle;" but he also describes an apparatus called "aquatic armour," which would enable those who were covered with it to walk under water. This apparatus is engraved in Schott's work, and shows a man walking into the water, with a covering, like a small diving-bell, over his head, descending nearly to his feet.

In England a diving-machine was foreshadowed by Roger Bacon; and his great namesake, Francis Bacon, describes it as a reservoir of air, to which labourers upon wrecks might resort whenever they required to take breath. He thus describes it:—"A hollow vessel was made of metal, which was let down equally to the surface of the water, and thus carried with it to the bottom of the sea the whole air it contained. It stood upon three feet, like a tripod, which were in length something less

than the height of a man; so that the diver, when he was no longer able to contain his breath, could put his head into the vessel, and, having breathed, return again to his work."—*Novum Organum*, lib. ii.

The bell was next used in America, in 1642, by one Edward Bedall, of Boston, to weigh the ship *Mary Rosè*, which had sunk in the preceding year. Bedall employed two tubs, "upon which were hanged so many weights (600 pounds) as would sink them to the ground." The trial succeeded, and the guns, ballast, goods, hull, etc., were all transported into shoal water, and recovered. Next, the postscript to a volume by Professor Sinclair, Edinburgh, 1688, describes "how to buoy up a ship of any burden from the ground of the sea," and states that the late Marquis of Argyle, "having obtained a patent from the King, of one of the Spanish Armada, which was sunk in the Isle of Mull, A.D. 1588, employed James Colquhoun, of Glasgow, a man of singular knowledge and skill in all mechanical arts and sciences." "This man," he proceeds, "not knowing the diving-bells, went down several times, the air from above being communicated to his lungs by a long pipe of leather. He only viewed and surveyed the ship, but I suppose buoyed nothing up. Subsequently, the (then) late Lord Argyle employed the ingenious laird Melgin, who went down with a diving-bell, and got up three guns. A third and more successful trial was made; and a fourth by Captain Smith, who was so confident of recovering the gold supposed to be lost with the ship, that he would not admit a co-partner in the enterprise, which, however, came to nothing."

Among the oldest of representations of diving apparatus, Beckmann mentions a print in "Vegetius on War," 1511 and 1532, representing a diver with a cap, from which rises a long leathern pipe, terminating in an opening, which floats upon the water; also, a figure from "Lorini on Fortification," 1607, nearly resembling the modern diving-bell, and consisting of a square box bound with iron, furnished with windows, and used for the diver. In 1617, Repton's "water armour" proved useless. In 1671, Witsen excelled in the construction of the diving-bell, which he erroneously states was invented at Amsterdam. In 1679, Borelli, the Neapolitan physician, is stated to have invented an apparatus by which persons might go a considerable depth under water, remain there, move from place to place, and sink or rise at pleasure; also a boat, in which two or more persons might row themselves under water; but the practical worth of these machines is much doubted.

The next claimant upon our list is William Phipps, born at Pemaquid, in 1650. When of age, he built a ship at Sheepscote; he afterwards followed the sea, and subsequently became Governor of New England. He attempted to raise treasure from the wreck of a Spanish ship, sunk on the coast of Hispaniola—with what apparatus we are uninformed. His earliest experiment failed; but he prosecuted his scheme, and at length obtained the patronage of the Duke of Albemarle, son of the celebrated Monk; and in 1687, after many difficulties, he succeeded in raising a large quantity of treasure, with which he returned to England, where he was knighted for his enterprise. Most accounts state that the property he recovered amounted to £200,000; but in the "Life of Sir William Phipps," published anonymously in 1697, and attributed to Increase Mather, it is stated at £300,000. There is a popular American opinion, that the Mulgrave family, of which the present head is the Marquess of Normanby, was descended from the above Sir William Phipps, which is a mistake: the founder of the Mulgrave family being Constantine John Phipps, Commander of the unsuccessful Arctic expedition in 1773, who was raised to the British Peerage as Baron Mulgrave, of Mulgrave, County York, in 1790.

The next improver of the diving-bell was Dr. Edmund Halley, who in the "Philosophical Transactions" described the defects of the bell, and suggested a remedy for them. This paper alone would be sufficient, although it does not enter into the early history of the machine, to contradict the erroneous statement which has been made, that Halley was the inventor of the diving-bell.

The diving-bell, in its simplest form, is a strong heavy vessel of wood or metal, made perfectly air and water tight at the top and sides, but open at the bottom. If such a vessel be gradually lowered into the water, in a perfectly horizontal position, the air which it contains cannot escape, and therefore the vessel cannot become full of water. This may be readily illustrated by plunging a glass tumbler in an inverted position into a vessel of water, and placing a piece of cork, or any other substance that will float on the surface of the water, under the tumbler. If a bit of burning matter be laid upon the cork-float, it will continue burning, although the glass and all that it contains be plunged far beneath the water; thereby proving that the upper part of the cavity of the glass is occupied by air, and not by water. Still, the water fills a small part of the cavity of the glass, and rises more into it when it is plunged to a considerable depth than when the rim is only just immersed beneath the surface. This is caused by the condensation of the air contained in the glass, which, being very elastic, is condensed into a smaller space by the pressure of the superincumbent water, when the glass is plunged to a considerable depth, than it will occupy under the ordinary pressure of the atmosphere. When the diving-bell is used for descending to a very small depth, as the pressure of the water is small, it will not rise in the bell sufficiently high to be inconvenient; but at the depth of thirty-three feet, the pressure is so great as to compress the air into one-half of its original volume, so that the bell will become half full of water. At a greater depth it will rise proportionally higher in the bell, but it does not materially interfere with respiration, provided the descent of the bell be very gradual, as the air then balances the pressure from without. The principal effect of the increased pressure is felt in the ear, for when the condensed air has found its way into the cavities of the ear, the sensation then experienced is compared to that of having quills forced into the ears, or as if the ears were bursting. This continues until the pressure of the air on each side of the tympanum is balanced. But while the mere condensation of the air in the bell does not render it unfit for respiration, it would soon become so if no means were provided for renewing it from time to time, as it becomes vitiated by repeated respiration. Dr. Halley provided a remedy for this inconvenience, and for that of the contracted space left free from water, when, by being at a great depth, the air is compressed into a small volume, by a means of supplying the bell with any required quantity of fresh air without raising it to the surface.

The bell used by Dr. Halley was of wood, in the form of a truncated cone, the top diameter three feet, and the bottom five, and containing about sixty cubic feet. This he coated with lead, and so weighted it about the lower part that it would sink while empty, and would always remain in its proper position; that is, with the larger open end downwards, and its rim parallel with the horizon. In the top of the bell was a very strong glass window, and a cock to let out the foul air. About a yard below the mouth was suspended a stage, so weighted that it might hang steadily. The whole apparatus was suspended from a sprit attached to the mast of a ship, and provided with tackle, by which the bell might be raised or lowered; and the sprit might be slung round, so as either to carry the bell over the hull of the vessel, or to suspend it clear of her side. Air was supplied to the bell when under water, by two thirty-six gallon barrels, weighted with lead, to make them sink readily; each having an open bung-hole in the lower end, to let in the water, as the air in them condensed on their descent. There was also a hole in the upper end of each barrel, to which was fitted an air-tight leathern hose, long enough to fall below the bottom of the barrel, and so weighted that it would fall naturally in that position. These air-barrels were attached to tackle, by which, with the labour of two men, they might be made to rise and fall alternately, like the buckets in a well; and by lines attached to the lower edge of the bell, they were so guided in their descent that the mouth of the hose always came directly to the hand of a man who stood upon a stage suspended from it. As the apertures of the hose were, during their descent, always below the level of the barrels, no air could escape from them; but when they were turned up by the attendant, so as to be above the level of the water in the barrels, the air rushed out with great force into the bell, the barrels becoming at the same time full of water. By sending down these barrels in rapid succession, the air in the barrel was kept in so pure a state that five persons remained in the bell, at a depth of nine or ten fathoms, for more than an hour and a half at a time, without injurious consequences; and Halley states that he could have remained there as long as he

pleased, for anything that appeared to the contrary. Besides, the whole cavity of the bell was kept entirely free from water, so that Halley sat on a bench, diametrically placed near the bottom, wholly dressed, with all his clothes on. He only observed that it was necessary to be let down gradually at first, about twelve feet at a time; and then to stop and drive out the water that entered, by receiving three or four barrels of fresh air, before he descended further. When arrived at the required depth, he let out, by the cock in the bell, a quantity of hot impure air, equal to the quantity of fresh air admitted to the barrels, when the foul air rushed up from the valve with such violence as to make the surface of the sea boil, and cover it with a white foam, notwithstanding the great weight of the water above. "Thus," says Halley, "I found I could do anything that was required to be done just under us; and by taking off the stage, I could, for a space as wide as the circuit of the bell, lay the bottom of the sea so far dry, as not to be over shoes on it. And by the glass window so much light was transmitted, that when the sea was clear, and especially when the sun shone, I could see perfectly well to write or read, much more to fasten or lay hold on anything under us to be taken up. And by the return of the air-barrels I often sent up orders, written with an iron pen on small plates of lead, directing how to move us from place to place, as occasion required. At other times, when the water was troubled and thick, it would be as dark as night below; but in such case I have been able to keep a candle burning in the bell as long as I pleased, notwithstanding the great expense of air requisite to maintain the flame."

Having by these ingenious contrivances removed the principal difficulties attending the use of the diving-bell, Halley foresaw its extensive utility. He adds: "This I take to be an invention applicable to various uses, such as fishing for pearl, diving for coral, sponges, and the like, in far greater depths than has hitherto been thought possible. Also, for the fitting and planning of the foundations of moles, bridges, etc., upon rocky bottoms; and for the cleaning and scrubbing of ships' bottoms when foul, in calm weather at sea. But," he adds, "as I have no experience in these matters, I leave them to those that please to try." To several of these purposes the diving-bell has, since the date of this paper (1717), been applied with great advantage.

Next, in 1732, Martin Triewald, a Swedish "Captain of Mechanics," expressed an opinion that no apparatus but that on the principle of the diving-bell could be safely used at great depths; and he mentions a man, then sixty-three years old, who had followed the business of diving with the common bell ever since he was twenty. Triewald's diving-bell was of copper, tinned inside, smaller than Dr. Halley's bell, and managed by two men. A stage for the diver to stand upon was suspended at such a depth below it, that the man's head could be but little above the level of the water, where the air is cooler and fitter for respiration than in the upper part of the bell; and a spiral tube was attached to the inside of the bell, with a wide aperture at the bottom, and a flexible tube and mouthpiece at the top, so that when the diver was up in the bell he might inhale cool air from the lower part, exhaling the foul air by his nostrils. Dr. Halley's air-barrels are applicable to a bell of this construction. Instead of windows of flat glass, Triewald used convex lenses to admit light to the bell. They are used to the present day. In clear weather they have been known to concentrate the sun's rays so as to burn the labourer's clothes inside the bell, when exposed to the focal point, and this when the machine was twenty-five feet under the surface of the water.

In 1775, Mr. Spalding, a grocer, of Edinburgh, experimented with Halley's diving-bell, with a view to recover property from a wreck on the Fern Islands; and he made certain improvements on Halley's bell, for which, in 1776, the Society of Arts rewarded him with twenty guineas. The improved bell contrived by him was so light that, with the diver, and weights attached to the rim, it would not sink. The necessary weight added was suspended from its centre by a long rope, which was so mounted on pulleys that the diver could either draw the balance-weight up to the mouth of the bell, or allow it to fall considerably below it. Thus, by letting the weight down to the bottom, the divers could anchor the bell at any required level, or prevent its further descent if they perceived a rock or part of a wreck beneath it, which might otherwise overturn it. Also, by hauling in the rope while the weight was at the bottom, the persons in the bell might lower themselves at pleasure. Then, near the top of the bell, a horizontal partition divided off a chamber that might, by openings and valves, be filled either with water or air from the lower part of the bell, so as to alter the specific gravity of the whole machine, and thereby cause it to ascend or descend as required. The bell was supplied with air by an apparatus resembling Halley's; and ropes, stretched across the bell, were used instead of seats and platforms for standing on. Thus the persons in the bell were enabled, in case of accident, to raise themselves to the surface without any assistance from above. A long-boat carried the signal-lines and tackle for working the air-barrels. Mr. John Farey, jun., next improved Spalding's apparatus by making the upper chamber without valves, and used it as a reservoir of condensed air, to be filled by forcing-pumps in the partition, besides other provisions. Farey also recommended that the men should be attached by ropes to the bell, so that, in case of falling, they should not sink.

Smeaton was the first to apply the diving-bell in civil engineering operations, in 1779, in repairing the foundations of Hexham Bridge. The bell used on this occasion was an oblong box of wood, supplied with air by a pump fixed on the top. In Ramsgate harbour this was used at a great depth, the supply of water being forced through a flexible pipe by a forcing-pump in a boat. This bell was of cast iron, and it weighed 50 cwt. Since Smeaton's time the diving-bell has been employed with great advantage in submarine works—sometimes in situations in which a coffer-dam could not be constructed, or the required operations performed by any other means. The mode of suspension differs according to circumstances—over the side or end of a vessel, through an opening in the centre of a barge, from framework between two barges, or from a scaffolding supported by piles. The operations upon the wreck of the *Royal George* at Spithead were first surveyed by the diving-bell in 1817. The celebrated Scottish engineer, John Rennie, on this occasion improved the apparatus for moving the bell in any direction.

A substitute for the regularly-constructed diving-bell was employed in the recovery of treasure and stores from the wreck of the *Thetis* off Cape Frio in 1830, by using a one-ton ship's water-tank, with eight inches of iron riveted to the bottom to give it more depth, and having attached to it eighteen pigs of ballast (17 cwt.) to sink it, when the greater part of the property was recovered.

The Nautilus submarine machine is an American improvement upon the old diving-bell. It is nearly cylindrical, with a spherical top; and the working apparatus, on board a barge floating near, consists of a steam-boiler, a cylinder or reservoir, and a condensing or air-pump. The workmen being stationed in the machine, water is admitted into two chambers, as ballast, to cause the nautilus to descend to the bottom; while the air is drawn through hose from the reservoir in the barge. As soon as the air thus drawn is sufficiently condensed, a cover to the bottom is raised, and communication obtained. Not only do persons thus remain under water for a considerable time, but should the hose communicating with the reservoir become disconnected, no danger can ensue to those in the machine, as they can, by means of the compressed air within the bell itself, expel a portion of the water, and thus enable themselves to rise to the surface.

A diving-machine contrived by Klingert, of Breslau, about the year 1800, was so arranged that it would rise or fall by the motion of a piston in a cylinder in the lower part of the apparatus, by which the diver could vary the density of the air at pleasure. A very simple apparatus to enable a person to dive without a bell or either of the machines here noticed, was invented in 1839 by Mr. W. H. Thornthwaite, of Hoxton. It consists of a hollow belt of india-rubber cloth, to which is attached a strong copper vessel, into which air is forced by a condensing syringe until it has a pressure of thirty or forty atmospheres. The belt is then put on in a collapsed state, so that it affords no buoyancy, and does not impede the descent of the diver; but when he wishes to rise he opens a valve, by which the condensed air escapes from the copper vessel into the belt. The entrance of the air expands the belt, which, when filled, affords sufficient buoyancy to raise the diver immediately to the surface.

PRACTICAL PERSPECTIVE.—XIII.

THE PERSPECTIVE OF POLYGONS.

We now proceed to study the method of obtaining perspective projections of polygons. Students who have worked through the course laid down in lessons in "Projection" will have no difficulty in realising the two plans drawn under the picture-line; that of Fig. 63 as the plan of the hexagonal prism standing on its end, and that of Fig. 64 as the plan of the object when lying on its side.

We require, in the first instance, to put into perspective the plan of Fig. 63, and to do this we must first enclose the regular hexagon, A B C′ D E F, by the rectangle G H I J.

This rectangle is then put into perspective in the usual method, by drawing lines from H and I to the centre of the picture, by describing the quadrant J J′, and from J′ drawing a line to the point of distance, cutting I C in *j*; then a horizontal line from *j* will cut H C in *g*, and will thus give the perspective projection of the containing rectangle.

Now from C′ and D draw lines to the centre of the picture, cutting *g j* in *a* and *f*. The line *a f* is then the distant side of the hexagon corresponding with C′ D in the picture-line.

Now in Fig. 63 lines drawn to C from the points corresponding to these gave the width of the distant side, but in the present case this would not answer this purpose, for the distant side, *a b*, is of a different size from the near one, A B.

It is therefore necessary to set off the real width, *a′ b′*, on the picture-line (Fig. 66), and lines drawn from these to the centre of the picture will cut the distant line of the containing figure in *a* and *b*, the points required.

From C set off D, the distance of the point D from the foreground, and draw a line from D to the point of distance, cutting the line C. From this intersection draw a horizontal line, cutting the side of the containing figure in *d*.

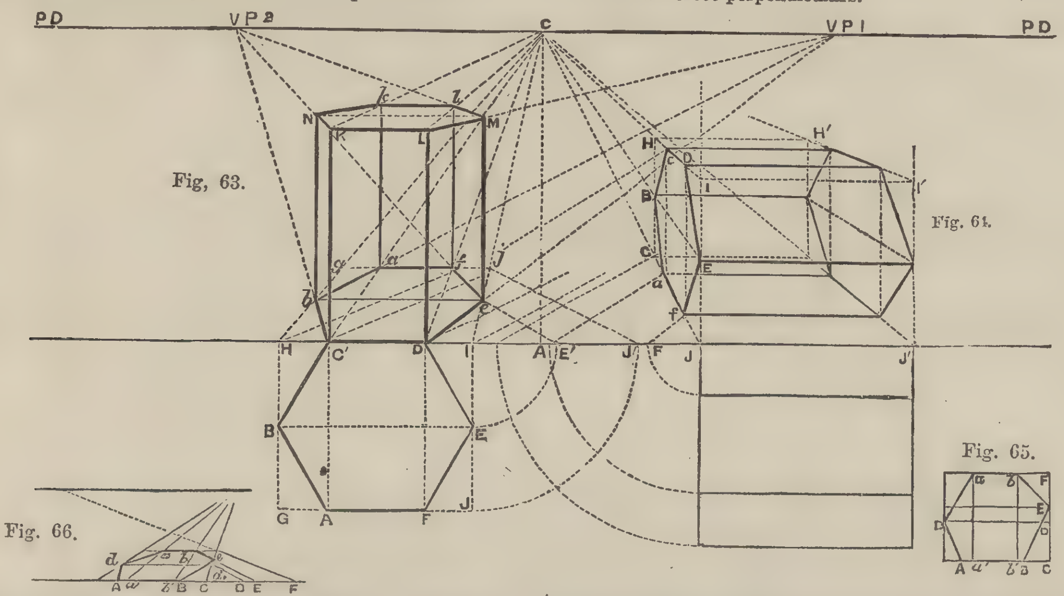
Join A *d* and *d a*.

From C set off the length C E (taken from Fig. 65), and draw a line from E to the point of distance, cutting the line C in *e*.

Join B *e* and *e b*, completing the figure, which, as will be seen, is not reversed.

We now return to Fig. 63, with the view of completing the prism. On C′ D raise perpendiculars, C′ K and D L, and join K L. This will give one of the vertical sides of the prism, parallel to the picture-plane.

At *b* and *e* erect perpendiculars.



Fig, 63.

From I describe the quadrant E E′, and from E′ draw a line to the point of distance, cutting I *j* in *e*.

From *e* draw the horizontal line *e b*.

Join C′ *b*, *b a*, also D *e*, *e f*, and these, with the two lines C D and *a f*, already drawn, will complete the plan.

The student, on examining this figure, will be again reminded of the principle already laid down, that all lines which in the object are parallel to each other vanish in the same point; for he will see that the lines in the plan which unite A C′, F D, G H, and I J, being at right angles to the picture-plane, converge to the centre of the picture, and that the lines D *e* and *b a*, which in the plan are parallel to each other, converge to VP1 in the projection, whilst C′ *b* and *e f* converge to VP2.

Before proceeding with this figure, we may call attention to the fact that the perspective projection of the plan represents the original figure as if turned over on the line H I, so that the points which in the plan are in the foreground are seen in the distance in the perspective projection. In this figure, which is equilateral and equiangular, this is of no consequence, but under other circumstances it might be important that the points in the near side of the plan should be shown in the foreground in the projection, and therefore another method is shown in Fig. 65, which will apply to irregular as well as to regular figures.

Let Fig. 65 be the plan of an irregular hexagon which is to be put into perspective.

Having drawn around it the containing rectangle, and having put this into perspective, as shown in Fig. 66, mark the points A and B for the nearest side of the figure.

Now it is evident that the prism consists of six equal rectangles, and that as K L is parallel to C′ D, the upper edges of all the sides will be parallel to those immediately beneath them; and as it has been shown that all lines parallel to each other vanish in the same point, it will be evident that lines drawn from L and K to VP1 and VP2 will give the edges LM and NK, which in the object would be parallel to D *e* and C′ *b*.

From *a* and *f* erect perpendiculars; from K and L draw lines to the centre of the picture, cutting them in *k* and *l*; and join *k l*.

Then the rectangle *a f k l* will be the perspective representation of the distant side of the prism, which, like C′ D K L, is parallel to the plane of the picture.

Join M *l* and N *k*, which will complete the top of the prism; and it will be seen that these lines produced will end in the same vanishing-point as the other edges of the object to which they are parallel.

Fig. 64 is the perspective projection of the same prism when lying on one of its sides, so that its hexagonal end is at right angles, and its long edge is parallel to the plane of the picture. It is hoped that previous practice will have enabled the student to work this study without the diagram being completely lettered, and with but few instructions.

The plan is, in the first place, to be projected, and at J the end elevation of the enclosing rectangle is to be put into perspective. This process is also to be carried out at the other end of the plan, and a solid rectangular block will be formed, which will seem as a case containing the prism.

Next, mark from J the points F and A, which may be done by describing quadrants from J; and from F and A draw lines to the point of distance, cutting J C in *f* and *a*. At these points draw perpendiculars, meeting I H in C and D.

On the perpendicular J mark off the height E, and from that point draw a line to the centre of the picture, cutting G H in B.

Join *f* E, E D, D C, C B, B *a*, *a f*, and so complete the end of the prism. The opposite end will be projected by simply drawing horizontal lines from the points already formed, to meet the sides of the containing figure.

EXERCISE 55.

The scale is $\frac{1}{4}$ inch to the foot; height of spectator, 6 feet; distance, 16 feet.

Subject, a prism, the ends of which are regular hexagons of 3 feet side, and the length of which is 8 feet.

Put this object into perspective when at 4 feet on the left of the spectator, its end being vertical and at right angles to the plane of the picture.

EXERCISE 56.

Put into perspective the same object when lying at the same distance on the left of the spectator, but 10 feet within the picture.

EXERCISE 57.

Give the perspective projection of the same prism when lying on one of its sides, its hexagonal end being in the foreground and parallel to the picture-plane, the nearest angle being 6 feet on the left of the spectator.

EXERCISE 58.

Put into perspective the same prism when lying at 5 feet on the right of the spectator, its hexagonal end being parallel to and at 8 feet within the picture.

EXERCISE 59.

Give a perspective view of the same prism when standing on its hexagonal end, at 4 feet on the right of the spectator, and 6 feet within the picture, the surface facing the spectator, and also that beyond it being parallel to the picture.

We now propose to show the method of projecting polygonal objects when placed at angles other than right angles to the picture-plane.

The subject of this lesson is a pentagonal prism, of which Fig. 67 is the end elevation, and Fig. 68 the plan.

Having found the vanishing-points and measuring-points, according to the position of the plan C E G F, and having projected the plan, enclose the end elevation, A B C′ D′ E′, in the rectangle C *c e* E, and put this into perspective as in Fig. 64.

Mark on the picture-line the points A, B, and D, and from them draw lines to the measuring-point, cutting C *e* in *a*, *b*, and *d*.

The length *a b* will be the perspective representation of the base of the pentagon, and a perpendicular drawn from *d* will cut *c e′* in *d′*, the upper angle of the pentagon.

Now on the perpendicular C mark off the height C′, and draw a line to the vanishing-point, cutting *e e′* in E′.

Join *a* E′, E′ *d′*, *d′* C′, C′ *b*, which will complete the perspective projection of the pentagonal end of the prism.

The distant end will be projected by drawing lines from *a*, *b*, C′, *d*, *e*, to VP2, cutting the sides of the distant containing figure, as in the former example.

EXERCISE 60.

Put into perspective a pentagonal prism lying so that its end is at right angles to the plane of the picture, at a given distance on the right of the spectator and from the foreground. Scale and measurements at pleasure.

EXERCISE 61.

Give the perspective projection of the same prism when lying so that its edges are at right angles to the plane of the picture—the object to be on the right of the spectator and within the picture.

EXERCISE 62.

Put into perspective the same object when lying on one of its sides, so that its pentagonal end is vertical and at 50° to the picture-plane, the object being placed on the left of the spectator and in the immediate foreground.

EXERCISE 63.

Give the perspective view of the prism when lying so that its pentagonal end is at 40° to the picture-plane, at a given distance backward, and on the right of the spectator.

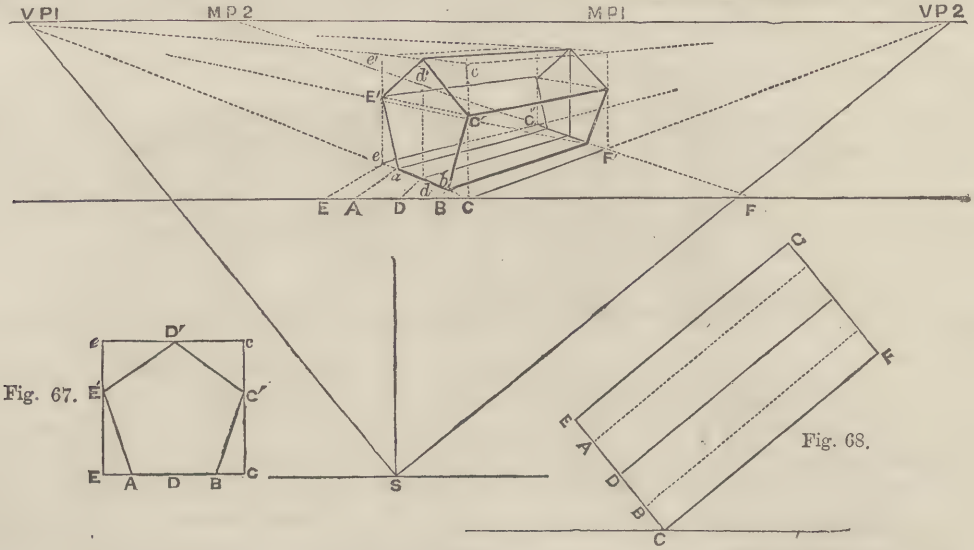


Fig. 67.

Fig. 68.

EXERCISE 64.

Scale, $\frac{1}{4}$ inch to the foot. Height of spectator, 6 feet; distance 18 feet.

Subject, a prism, the end of which is a regular pentagon of 2 feet side, and the length of which is 2 feet.

Put this prism into perspective when standing on its end, one of the angles of which is at 6 feet on the left of the spectator, and of the two adjacent sides (that is, the two sides meeting at this angle) the one nearest the spectator recedes from the picture at 30°.

EXERCISE 65.

Give the perspective projection of the same object under the same circumstances, but at 5 feet on the right of the spectator, and 8 feet within the picture.

SANITARY ENGINEERING.—VI.

GAS-METERS.

IN our previous papers upon gas we have given some idea of the method of its manufacture and distribution; its applicability to small establishments, under the head of "Private Gas-Works;" and also some idea as to its practical use in lighting large interiors, under the head of "Sunburners." The object of our present paper is to give a short account of the way in which the gas we burn is measured, and the mechanical appliances available for that purpose. Water supply and payment, throughout the metropolis at all events, are regulated by an arbitrary set of rules entirely out of the control or supervision of the general consumer. The house is rated at a certain figure, and

whether more or less water is consumed the payment is the same. But with gas the case is different in the great majority of instances. As far as private consumption is concerned, the gas is measured before it is burnt; in other words, it is burnt by meter, and the consumer pays for what he burns—no more and no less. How is the quantity ascertained? This we shall now proceed to show, premising that the motive power of the measurement is the pressure of the gas itself. In a former paper describing the gas "regulator," we indicated how the pressure of the gas, by the action of a valve, could be brought to bear upon the "quantity" of gas delivered and the amount of the supply, and then regulate the consumption; and the same power, the pressure at which the gas is supplied, is utilised by the machinery we shall describe in the sequel to register its own volume, and record the quantity consumed.

The principle thus broadly stated may be adopted either with the aid of water or without. Where water is used as the medium through which the gas is admitted, the machine is called a wet meter, and where no water is required, a dry meter; each system has its peculiar advantages for different purposes. The simplest form of wet meter is a horizontal cylinder closed at the end, and encased within another in which it revolves; the inner cylinder is divided into what may be called quadrants, by a series of partitions passing through its axis, and showing in section like the spokes of a wheel; and into one of these quadrant spaces at a time the gas is introduced by the supply-pipe at the water-level. As the gas enters the section of the cylinder, it gradually, by its pressure, forces up the partition, and, as we may say, turns the wheel. When a certain point in the revolution is reached, an opening is provided into the external case of the meter, the gas passing into the pipes on the other side; and the gas in the quadrant being thus released, the section below it becoming subject to the same action, is in its turn raised by the pressure of the gas, and discharges its volume of gas in the same way. In the case before us, supposing the cylinder divided into four, when each of these has been filled and discharged a revolution is completed, and a certain number of cubic feet of gas have been passed forward for consumption. The cylinder is made to revolve upon an axis, which projects beyond the internal casing, and on which is fixed a toothed wheel, which, by an ingenious arrangement of clockwork, is made to register the number of revolutions, and is so arranged that on the series of little dials on the front of the upper portion of the gas-meter, with whose appearance we are all familiar, the consumption of cubic feet is automatically registered—tens, hundreds, thousands, and tens of thousands, each being recorded on its separate dial. The inspector, who comes to take an account of the gas burnt, has only to register the figure then indicated, and his record is complete.

In dry meters the same method of registration is adopted—*i.e.*, by means of clockwork, and the first motion is obtained by the alternate expansion and contraction of a series of movable diaphragms, the rotating motion thus obtained being registered in the ordinary way.

Nor is the amount of gas passed through any particular meter a matter of speculation; it is ascertained by actual experiment, not by any private individual, but under the absolute provision of an Act of Parliament; this is known as the "Sale of Gas Act" of 1859, and is the grand controlling power over the gas company and private individuals as far as legislation is concerned. Its action is, unfortunately, only very partial; but as our present object is technical and not legal, we may remark that its operation will very probably be extended. It regulates the construction and stamping of meters, and provides for their deposit with the proper authorities; and to show the detail into which it goes, and the definiteness of its provisions, we will quote the second clause only, which may be taken as the key-note to the whole:—

"Clause 2. After the passing of this Act, the only legal standard or unit of measure for the sale of gas by meter shall be the cubic foot containing 62·321 pounds avoirdupois weight of distilled or rain water, weighed in air at the temperature of 62 degrees of Fahrenheit's thermometer, the barometer being at 30 inches, except as relates to contracts made before the passing of this Act, by which a different unit of measure is adopted, which contracts may not be renewed."

Inspectors of meters are appointed, and meters, after being tested according to certain provisions, into the detail of which our space does not allow us to go, are required to be stamped, the stamp attesting their correctness as ascertained by experiment. There are fines, penalties, and various other provisions in the Act, for its proper enforcement; with the details of which we will not trouble our readers.

A very important element in all matters of gas calculation is the pressure, which is thus measured:—A tube bent in the form of the letter U, with the ends open upwards, is partially filled with water, this water being perfectly level in both tubes; one end is then connected with the gas-pipe, of which the pressure has to be tested, and the power of the gas lifts the water in the other tube, and depresses it in that to which it is connected; the difference of level thus obtained is measured in inches and tenth parts of an inch. We may say that a fair average working pressure is somewhat less than an inch; but as all experiments are more delicate if made at a low pressure, the regulation testing and marking of meters and standards is fixed at a pressure of five-tenths only, or half an inch.

In localities where there is a great difference of level, the well-known tendency of gas to rise produces the result of giving a much higher pressure at the upper than at the lower portion of any range of pipes; and in practice it is found that a difference of 100 feet is represented by about an inch of pressure; so that a house situated at a height of, say, 200 feet above the gas-works, would indicate a pressure of three inches, supposing the gas delivered on the lower level at a pressure of one inch.

We now proceed to say a word or two on the comparative advantages and disadvantages of wet and dry meters; and may mention, as a fact, that the use of dry meters has much increased of late years, especially in the London district; and there are some public companies who now only fix dry meters; while throughout the Birmingham district wet meters only are used. Each system has its advocates, and we will briefly allude to the arguments on either side.

The most serious objection to the wet meter is the liability of the water to freeze, when, of course, the supply of gas is stopped; but as meters are usually within the house, a few very simple precautions will effectually prevent this happening, and it is not found in practical working to be an objection of any moment.

The next difficulty is the irregularity to which the water-level is subject from evaporation and other causes. It will be evident that if a meter measure correctly at the true water-line, should the water rise above that point, the measuring chamber through which gas passes is diminished in size, while, if the water is allowed to fall below it, more gas will pass than is measured in a precisely parallel ratio. Hence the constant recommendation of the gas inspectors to put plenty of water in the meter. And here the point at which facility is afforded to any one with dishonest intentions to obtain more gas for his money than he is fairly entitled to by altering the level of the water in the meter. Many ingenious inventions have been made in the way of manufacturing "compensating" meters, which, by self-acting machinery, shall regulate their own water-level; this object being generally obtained by means of a float, which, when the water falls below a certain level, sets in motion by means of a spring or otherwise a "spoon," as it is technically called, which, from a reservoir specially provided, lifts sufficient water into the meter proper to restore the water-line. Compensating meters have been very numerous, but a great proportion of them have failed in practice from various causes; and some companies prefer relying upon the vigilance of their officers rather than resort to employing any of these methods.

Dry meters, as now ordinarily constructed, are either oblique action or direct action. In the oblique action meter the square form is usually adopted for the one side of what we may call the bellows portion, the movable part being divided into four triangular sections meeting at a point in the middle. these sections being connected by what may be called gussets of leather, and hinged all around the outer edge; when the gas is admitted the centre is gradually forced out, and the pyramidal chamber thus formed measures the gas. The metal of which the plates are formed must be of a quality to resist the corrosive action of gas and its condensation.

In the direct action dry meter the circular form is usually adopted, and a circular disc of metal is united to another all

round its circumference by leather, in the same way. When the gas is admitted, the discs are gradually forced apart, and the contents of the flattish cylinder of gas between them forms the measuring unit of the meter, which may vary in size almost indefinitely from a three-light meter to a three-thousand light meter, or even larger. We may here remark that the nominal power of a meter is always very much below its actual capacity, and that any meter will safely and satisfactorily supply double at least the number of lights represented by its description. The objections to the dry meter are, that the leather with which its diaphragms are constructed is subject to variation of flexibility by change of temperature, and that, therefore, it will record irregularly at different times of the year; that it is not so lasting as the ordinary water meter, and that when out of order it is not so easily detected. There is also this objection to it, that it is not so perfectly regular in its delivery, the alternate action of the chambers sending the gas forward in a series of puffs, as it were, and not in one regular stream. This objection does not deserve any weight in ordinary practice, but in experimental uses, when it is desired to obtain an exact record of short spaces of time for purposes of comparison and calculation, certain minute irregularities of this kind have been known to occur.

We may, however, mention, as a matter of some interest, that the immense meters at the works at Beckton—the largest gas-works recently erected—are wet meters; the reason being, that all the large "station" meters, as they are called, having to receive the gas somewhat warm, with its full proportion of tarry deposit, the wet form of meter is adopted for the reason that a certain amount of deposit, which always takes place at this point, is more readily removed from a wet meter. In ordinary house meters this does not take place, and therefore dry meters may be safely introduced.

We cannot attempt to decide in favour of either, but have endeavoured to state, as fairly as we can, the arguments on either side of the question of "wet meters *versus* dry."

OPTICAL INSTRUMENTS.—X.

BY SAMUEL HIGHLEY, F.G.S., ETC.

APPARATUS EMPLOYED FOR EDUCATIONAL DEMONSTRATIONS.

It may seem strange, to some absurd, that we should ask learned teachers to devote serious attention and consideration to that reminiscence of the nursery, the galanty-show—to that toy of our boyhood, the magic lantern; but many scientific things when first discovered, either from their remarkability or beauty, have excited public interest only to the extent of being regarded as pleasing toys, till in the course of time their practical value has been discerned, and they have ranked thereafter among the implements of applied science. Such was the globe of water, magnifying in distorted form the fly or flower, till in the hands of science it sprang into that exquisite refinement on optical knowledge—the microscope—the discoverer of hidden worlds of life, and of the seat or form of disease within the inmost walls of the human frame.

Such the kaleidoscope, the tin case with its bits of coloured glass, regarded long as only a wonder from the fair, till in practical hands we find ourselves indebted to its aid for many of the beautiful geometric designs which ornament our walls or floor.

Such the camera-obscura, the discovery of Baptista Porta of Padua, till the progress of chemical knowledge revealed to us the means of fixing its fleeting images; and even then its light-imprinted products, together with their adjunct the stereoscope, were little thought of in their practical and educational applications till recent days.

So with the magic lantern. Who is there over forty years of age who cannot remember in the days of his youth questionable-looking men going through London streets or country towns, crying "Galanty Show! Galanty Show!" as soon as damp and dreary winter set its mark upon the waning year? Who forgets how crude the apparatus was, suggesting a converted tea canister, illumined by a smoky, fat-trimmed lamp, or how coarse but laughter-moving the stock of slides—old Joe Grimaldi rolling his eyes—skeleton Death that raised his dart—the terrific upper and under-cut combat between the Englishman and the Frenchman—the fierce Turk's head that came out of the lily, and the black woman out of the cauliflower—all done, as we are assured, by wonderfully complicated mechanism, that cost a mint of money? Who can forget that party-spirit, moving scene of all the parish hanging on to the respective tails of the two fighting dogs or the never omitted "Pull Devil—Pull Baker," that wound up the exhibition? Ah! *tempora mutant mores.* Skeletons have gone out of fashion—and the D—— must never be mentioned to ears polite now-a-days, much less sold as a marketable commodity in the shape of a slide for the magic lantern. Then came a step towards improvement on such primitive entertainments in the shape of the "Phantasmagoria," that excited general wonderment at the old Adelphi Theatre, with its awe-inspiring effects. A few years later, and Child's dissolving views at the Adelaide Gallery, Colosseum, Alhambra, and the Polytechnic, evidenced a great advance in the right direction, and led to the production of the finest hand-painted slides and mechanical effects that have ever been produced for the magic lantern, as much as fifteen and twenty guineas each having been paid to the artists who produced them.

In recent years came the application of photography to the magic lantern, and it became apparent that that which had only been employed for mere amusement was destined to become, in the hands of the professor and schoolmaster, an important philosophical instrument of great educational value; yet I am surprised to find how few there are among those whom it most concerns—viz., the professed "educationists" of the day—who are cognisant of the extent to which the magic lantern may be employed for school teaching and class demonstration. By the aid of the magic lantern we can deal with beams of parallel, converging, or diverging rays of light, which, brought to bear upon suitable apparatus and appliances, enables us to exhibit the most important optical phenomena, and demonstrate the laws of plane and polarised light deduced therefrom.

Aided by mechanical contrivances and transparent orreries, the astronomer can avail himself of the lantern for illustrating his discourse on those vast and unlimited realms of space beyond our own globe, which are studded with other planets, star-groups, comets, and meteors; while availing himself of photography, he can present to his audience the self-depicted portraits of the sun and moon, the phases of eclipses, those mysterious protuberances that surround the sun's edge and extend to a vast height into its photosphere, the dark spots that travel over the sun's face, and the spectra of the heavenly bodies.

It is when photography is thus applied to the production of transparent diagrams for the magic lantern that the educational value of that instrument for a wide range of illustration becomes palpable. Within a disc three inches in diameter, all the details of a microscopic object of the most complex structure—the crevassed range of the Mer de Glace, or the wide-angled landscape of the Falls of Niagara—may be clearly depicted in a manner that could not be approached, much less rivalled, by a hand-painter, even if a surface four times the size of that specified were given to him to work on, which would then entail a lantern four times the size of that required for the photograph, and increased bulk of apparatus implies increased expense in every direction.

Undoubtedly many subjects have been truthfully and artistically produced for the magic lantern by the hand-painters; but can any artist (even if he be a pre-Raphaelite) for one moment pretend to cope with Dame Nature in her artistic moods, or hope to introduce the amount of detail she, with her undulating brushes of light, fixes upon the film which her assistant, the chemist, has prepared for her? For it must be borne in mind, that while the artist delights in broad effects, the teacher of science regards *detail* as a *sine qua non*, their aims being different; and when we call upon Nature to depict her treasures with her own pencil, another requirement of the naturalist is ensured—the *truthfulness*—for we know our studies are then delineated by a faithful and an unbiassed hand. I have long been impressed with the conviction that a lecturer on natural history—and even on pathology—would welcome as a boon truthful transcripts of Nature that could be packed in a small space, and then shown by means of a lantern on a scale sufficient to arrest the attention of the student, for all persons who have had any experience in scientific educational matters know the value of appealing to the eye. Book knowledge, or that experience

gained even from the most graphic descriptions, is but of slight value to the student who would become a true naturalist. He must see—if possible, handle—the objects of his study.

The next best thing to this, is to be familiar with the most accurate delineations of the forms he wishes to become acquainted with; and here Photography offers her aid, and the magic lantern popularises her efforts. This mode of projecting on a screen enlarged delineations of the objects described by a teacher is very impressive, as the luminous diagram is of such a size, that every student in the largest lecture theatre can discern the most minute details, which is more than can be said of the ordinary paper diagrams usually placed before a class. But beyond this, when the photographs have been taken direct from Nature or from artistic productions correct as to the rendering of light and shade and angle of view, the image stands forth on the screen with all the roundness of Nature and perfect stereoscopic effect. Again, as only one subject is presented at a time, the attention of the student is fixed upon the object of the lecturer's description, and the listless eye cannot wander from one picture to another, as is too often the case when a number of paper diagrams are displayed at one time. There is one thing, however, that photographs cannot, as yet, effect—it can draw our pictures, but it cannot paint them. The day may come, however, when even that apparent miracle may be accomplished, for we must not forget that that great master in science, Michael Faraday, who passed from among us, not great in years, but great in the esteem of men, has bequeathed to Warren De la Rue the daguerreotype presented to him by Becquerel, whereon Nature had reproduced a coloured figure from her own spectral palette; and that precious specimen exists, unfaded—a promise for the future!

If we take a survey of the departments of science in which the lantern can be employed for class demonstrations, we shall find that

The mineralogist can employ photographic lantern slides for projecting on the screen large diagrams of chemical formulæ or tabular views of the classification of minerals—the spectroscopic characteristics of the elementary bodies—the typical forms of the crystallographic systems, and, by means of the opaque lantern, the characteristic forms and colours of minerals and rocks. By the lantern polariscope he may show the depolarising, dichroitic, uniaxial, biaxial, or tesselated characters of crystal sections; or by the lantern microscope he may show the particles of matter in the very act of grouping themselves under the force of crystallisation—the order of the magnetic curves, the action of weak currents on the needle galvanometer, or the acoustic figures of Chladni, Savart, and Lissajou—the decomposition of water into its constituent elements and their volumetric proportions, together with many other chemical, physical, and morphological demonstrations.

The botanist, either by photographs direct from Nature or from carefully-made drawings, or with preparations of the objects themselves (as the case best admits of), may display the specific character of plants—groups that illustrate the great natural divisions of the vegetable kingdom—their microscopic characters and geographical distribution—the absorption spectra of vegetable infusions, with other physical and chemical characteristics of plant-life.

The zoologist by the same means may demonstrate the osteology, the anatomy, microscopical characters, typical structure, and typical forms of the great natural divisions of the animal kingdom, and place before his students groups of animals characteristic of the regions of Europe, Asia, Africa, America, and Australia, and the ethnological types that characterise the same geographical divisions of our earth. As a rule it is preferable to take photographs direct from the living animals, as Haes has done in his admirable series from the Zoological Gardens, but in many instances this is impossible, and in some cases a diagrammatic treatment of the subject is preferable. This specially holds good with most of the oceanic forms of life; for when out of a sufficient bulk of their native element they collapse and look anything but as if they had been depicted "from the life."

Again, from the rarity of the subject desired, it may be necessary to resort to engravings; but no expense should be spared to procure them from the works of the best authorities, and in such style of execution as is to be found in the works of the Ray and Palæontographical Societies. In other cases, such as in representing the mollusca, the objects should be modelled in wax in connection with the real shell of the species, and the same applies to the tubed annelids.

The anatomist may avail himself of the method now advocated for showing *very large* diagrams of the various parts of the animal frame, *preparatory to showing the parts themselves,** and so preparing the students for the points they should then give special attention to—a matter of grave importance when demonstrations have to be made on the dead body in hot climates.

To secure negative photographs of anatomical subjects, I may here draw attention to a possible difficulty, and the means of surmounting it.

Some years since I made an attempt at St. Bartholomew's Hospital to photograph anatomical subjects that had been carefully prepared for me by Mr. Luther Holden; but, though from one to twenty minutes' exposure was given, nothing but a faint image presented itself. I first attributed this extraordinary failure to the miasma of the dissecting-room, but on the subject being photographed out in the open air, a fine negative was obtained. Our failure was really attributable to the yellowish light reflected from the buff walls common to dissecting-rooms, such yellowish light making little or no impression upon a sensitive photographic film; and this gives us a hint, if it be thought advisable to employ photography systematically at our hospitals. The walls of the operating-room must be left white or coloured blue—not that that colour will add any actinic power to the light reflected from such surface, for it is not an uncommon error amongst photographers to believe that by allowing the light of heaven to pass through blue glass increased actinic power is secured to their operating-rooms; but it must be observed, though a yellow glass will stop the progress of the chemical rays, a blue glass will add nothing to a passing beam, whether it be rich or poor in actinic rays. The same, of course, applies to reflecting surfaces.

A Russian professor of anatomy secured exquisite sections of various parts of the human body, with all the organs *in situ*, by completely freezing a subject into a solid rigid mass before making the desired longitudinal and horizontal dissections. The various sections were then photographed, and the resulting diagrams are admirably suited for lantern demonstrations.

The physiologist may make the heart or lungs of a man or animal write its rhythmic or irregular action on a piece of smoked glass, and the result can then be shown as a large diagram by aid of the lantern; and besides the employment of coloured diagrams, the circulation of the blood, together with many other functions of vegetable and animal organs, may be displayed by means of suitable contrivances.

The pathologist may avail himself of photography and the lantern for placing before his class truthful records of rare cases, occurring at his own hospital or in the clinical wards of other medical schools at home or abroad. In rare surgical operations, portraits of a suffering patient may be taken at a given moment and instantaneously, when it would be an act of barbarity to call upon the hand-draughtsman to perform such office. Such photographic records have for some years past been made at the Middlesex Hospital by Mr. Charles Heisch. Dr. Balmano Squire has employed this method for the delineation of skin diseases; and Dr. Diamond, many years since, produced a series of photographic portraits, illustrating the "Types of the Physiognomy of Insanity," in many cases the progress of the various stages of mental disease being periodically recorded by aid of the camera.

The microscopist may in some cases display the minute structure of natural or artificial objects themselves on a magnified scale by means of the lantern microscope; in other cases, especially in regard to the most minute forms, by means of positive transparencies obtained from negatives of objects that have been enlarged in the camera up to three inches in diameter, according to the methods successfully carried out by Reade, Delves, Shadbolt, myself, Crookes, Drs. Maddox, Abercrombie, and Wright, Woodward, Bockett and others, which are then enlarged to any extent by the lantern—a matter that cannot be effected by the

* This preparatory method applies generally to difficult or expensive demonstrations, when it is desirable to direct the attention of the student to the point to be observed when the object itself can only be shown for a limited time.

lantern microscope, as beyond a certain point of enlargement its optical aberrations become too pronounced when really great amplifying powers are employed.

The geologist may illustrate his lectures by views taken direct from Nature of the mine and the quarry; the natural cleavage of slaty rocks, or the stratifications of aqueous deposits; the disintegrating action of the atmosphere on granite and feldspathic rock; the stupendous erosive action of water as at Niagara Falls; the volcanic cone and crater as in Piazzi Smyth's photographs of Tencriffe; the eruptive geysers of Iceland; mineral veins of eruptive rocks or metallic deposits, or the characteristics of glaciers and glacial action.

The palæontologist may show the extinct forms of animal or vegetable life that mark the boundary line of great epochs in the world's early history; the weird skeletons of mighty animals, toad-like creatures as big as rhinoceri, reptiles larger than whales, birds as long-necked as giraffes, stags of gigantic size, and elephants as great as Behemoth, with the probable aspect of such creatures in their living state, as restored from their fragmentary remains (not by fanciful or hap-hazard guesswork, but by sound inductive reasoning founded on anatomical knowledge) by Cuvier, Owen, Waterhouse Hawkins; or even entire resuscitated landscapes, including both plants and animals, as Unger of Vienna has so artistically reproduced in his "Ideal Views of the Primitive World."*

The art professor may avail himself of these aids to education for reproducing faithful transcripts of celebrated works of the great masters in all ages, and stereoscopic images of the gems of sculptured art where it would be impossible to deal with the original, even if cost or space permitted, and enable him to point out the peculiarities of style that characterise the various schools of ancient and modern art.

The engineer may throw upon a ten-foot disc embodiments of great triumphs in mechanical skill that in their reality cover miles of ground—whether they be the aqueducts of ancient nations, or such bridges as in recent days span the Menai Straits or American valleys—and the details of construction of engines and machines of peace or war.

School Teaching.—As yet I have only spoken of the application of photography and the lantern to scientific and artistic demonstration; but in high-pressure days like the present, when the student has enough to do to make himself familiar with all the subjects he is expected to be more than superficially acquainted with, I believe such legitimate aids to education would be found admirably adapted for facilitating the scholar's labour, especially in regard to history and geography; for what is more likely to make a lasting impression on the schoolboy's mind, than placing before him accurate pictures of the subject of his studies, on such a scale as to become impressive while appealing to the eye, and so to serve as an artificial memory, giving the next best thing to the students having seen the subject of their studies in their reality, a matter usually impossible, unless we really possessed the power of rendering them *clairvoyant*, and could then take them back into time, or a tour round the world. I am firmly convinced that schoolmasters would save time and teach better were they to make geography and history subjects for evening lectures, illustrated by the lantern.

History.—He would be a bold man, however, who would venture to suggest to an Oxford or Cambridge don the introduction of a magic lantern for illustrating the university course on history. But why not? "Because it has not been done hitherto," is not a sufficient answer in these days of rapid progress and wide reform; for by a well-selected and carefully-executed series of photographs from authentic data, we may make the student familiar with the features of those who have been celebrated for good or for evil in politics, war, literature, science and art—the aspect of the people of various nations, their costumes, their habitations, from the mud hovel to the stately palace; the chambers in which they lived, prayed, or died; the vases and artistic decorations with which they decked them; the gods they worshipped, carved out of the living rock, cast in bronze, or built up in ivory and gold, and of prodigious size; their manners and customs, their implements of daily life; how they lived during peace and at war, their arms and armour, and modes of attack upon an enemy; in what grandeur they carried their illustrious dead to the grave, preserved or dispersed their remains, and recorded their achievements in monumental sculptures—in fact, the life-history of nations from the earliest records to the present day.

In placing such surveys of man's history on earth, in the form of *existing scenes*, we appeal to the eye in a manner the most impressive verbal or printed description, solely, could never convey to the mind, and so establish a more rapid method of instruction, of a kind not so likely to pass out of the student's head after he has left school or college.

But the thin edge of the wedge *has been* inserted—not only in the schools but the *colleges* of Russia. In 1863, after the close of the International Exhibition, I read a paper before the Society of Arts on "The Application of Photography to the Magic Lantern Educationally Considered," on which occasion every conceivable branch of education was illustrated according to the system advocated. That paper attracted the attention of a young officer in the Russian artillery, who has since become, not only a distinguished professor, but inspector of the military colleges of Russia; and with the courage of youth he determined to adopt the system therein advocated for his own lectures on general history, and sought my co-operation to that end; so in 1869, I found my notions of 1862 *un fait accompli*—the great authorities on Assyrian, Persian, Egyptian, Grecian, Roman, and mediæval history being ransacked to supply the necessary data for drawings or colour, and the results were exhibited at the Society of Arts in 1869.*

Geography may be illustrated by maps showing the political boundaries the power of nations has set up, or the natural divisions climate and other physical causes have stamped upon our globe; portraits of the types of men who inhabit its various regions; the vertical range of animals and plants from the greatest mountain heights to the lowest bathymetrical depths of the ocean, or their horizontal distribution over the face of the earth, and their limits in latitude and longitude; the physical phenomena that characterise its several regions, such as monsoons, hurricanes, water-spouts, mirages, snow-storms, glaciers, ice-fields, avalanches, and land-slips, thunder-storms, volcanoes, geysers, whirlpools, mountain torrents, caverns, coral reefs, stalactitic formations, and basaltic islands; the physiognomy of mountain peaks in relation to their mineral constitution and other physical features of the earth's surface; the buildings that characterise different nations, from the snow-hut of the Equimaux to the European palace, or those of peoples who have passed from the face of the earth, whether it be the pyramid of the Egyptian, the palace of the Assyrian, or the temple of the Aztec; the general aspect and characteristics of the great cities of the world, their engineering feats and art treasures; in fact, all such matters as educated people desire to be familiar with, and that give interest and vitality to geographical studies which the dry details and ever varying statistics of the old methods of instruction never imparted.

Descending to the artistic requirements of unscholastic life, what can be more delightful than to bring back reminiscences of travel, taken from our own points of view by means of the miniature cameras *at last* coming into vogue (cameras that are no longer a burden to the tourist); and on one's return from a summer trip, placing before family and friends enlarged transcripts, depicted by Old Sol, of the scenes that have given us health and pleasure. We can dwell no longer at present on subjects to which the art of photography may be usefully applied as a means of teaching in conjunction with the magic lantern, but we shall resume the subject in our next paper.

SEATS OF INDUSTRY.—XV.

LEEDS.

BY WILLIAM WATT WEBSTER.

ALTHOUGH Leeds is the chief centre of the flax-spinning and linen manufactures of England, the staple industry of the town is the manufacture of woollen cloths, for which it has long been famous. Leeds, variously spelled in old records, "Loidis,"

* "Ideal Views of the Primitive World in its Geological and Palæontological Phases." By Dr. F. Unger. Edited by Samuel Highley, F.G.S., etc.

* "On Photography and the Magic Lantern applied to Teaching History." (*Society of Arts Journal*, Vol. XVII., page 139.)

Ledes, etc., is mentioned by Bede, the ecclesiastical historian, and in the Domesday Survey; and soon after the Conquest a castle was built by Albert de Lacy on the eminence now known as Mill Hill, which was besieged by Stephen in 1139, and in which Richard II. was imprisoned in 1399, after his deposition. Leland, writing early in the sixteenth century, describes Leeds as "a pretty market town, subsisting chiefly by clothing, reasonably well builded, and as large as Bradford, but not so quick as it." The cloth trade had been introduced at least sixty years before this date. In his "History of the Great Rebellion," Clarendon speaks of Leeds, Bradford, and Halifax as "three very populous and rich towns, depending wholly upon clothiers."

Before the outbreak of the Civil War, Leeds was incorporated as a municipal borough, and in 1661, after the Restoration of Charles II. it received a charter, which was renewed by James II. in 1684. For centuries previous to and after the manufacture of cloth was commenced at Leeds, fairs were held there, at which the farmers of Lancashire and Yorkshire sold their wools and sheepskins to merchants from Hull and other ports, for shipment to Flanders, where they were worked up; a large portion of the wool finding its way back, in the shape of cloth, to the locality in which it had been grown.

Leeds is situated in the north-west of the West Riding of Yorkshire, in the middle of a fertile district abounding in coal, and possesses great natural as well as artificial facilities for trade. By means of the river Aire and the Calder Navigation, ships of 120 tons burden can come up to the town from the Humber and the German Ocean, while the Leeds and Liverpool Canal connects it with the Mersey, and railways branch out in all directions—to York, Hull, Manchester, Liverpool, Skipton, Lancaster, and two, by Derby and Lincoln, to London. The town is mostly built of brick, and the streets are, for the most part, narrow and irregular; but great improvements have been effected of late years, and in the centre and west end of the town there are now several broad thoroughfares, lined with handsome houses. On the south side of the Aire lie the extensive suburbs of Holbeck and Hunslet, which contain many large factories. The principal public building in Leeds is the Town Hall, a very elegant Corinthian structure, which was opened by Her Majesty in 1858, and which is adorned with several fine statues. The Mixed Cloth Hall, built in 1758, and the White Cloth Hall, for the sale of undyed goods, erected in 1775, are plain if not ugly edifices, but they possess a certain interest as monuments of a bygone system of trading. Previous to the opening of these halls the traders were in the habit of exposing their goods for sale on the parapets of the long wide bridge that spanned the Aire, and in an adjoining street, called the Briggate. The regulations under which the Mixed Cloth Hall was managed were very curious. This mart was built at the expense of the merchants and manufacturers, and the stands were held as freehold property. No person who had not served a regular apprenticeship to the mystery of making coloured cloths was allowed the use of the hall, which was only opened for business for one hour and a half on Tuesdays and Saturdays. "The market-bell," says one account, "rings at six o'clock in the morning in summer, and at seven in winter, when the markets are speedily filled, the benches covered with cloth, and the proprietors speedily take their stands; the bell ceasing, the buyers enter, and proceed with secrecy, silence, and expedition to bargain for the cloth they may require, and business is thus summarily transacted, often involving the exchange of property to a vast amount. When the time for selling is terminated, the bell again rings, and any merchant staying in the hall after it has ceased becomes liable to a penalty." The frequenters of the White Hall were subject to similar regulations.

Several of the institutions and charities of Leeds deserve to be noticed, among which is the Free Grammar School, founded in 1552, and rebuilt in 1860, at a cost of £15,000. This institution furnishes free instruction in classics and the elements of mathematics to the sons of all residents in Leeds, and four scholarships in Magdalen College, Cambridge, and an exhibition in Queen's College, Oxford, are open to the competition of its pupils. There is a somewhat peculiar charity in Leeds, known as St. John's Charity, and founded in 1705, which has for its object the training of girls for domestic service. Besides about a dozen smaller institutions for promoting popular education, Leeds possesses a Mechanics' Institute, in connection with which there is a library of upwards of 12,000 volumes, one of the most flourishing schools of art in the kingdom, capital day and evening schools, and a Working Men's Institute, with a large number of members, which furnishes newspapers and in-door and out-door games, and supplies refreshments at cost price, for a weekly subscription of one penny.

In 1775 the population of Leeds only numbered 17,117. In 1861 it had increased to 207,165, in 1865 to 224,025, and at the census of 1871 it had reached 259,201. This rapid growth corresponds strictly with the progress of its manufactures, and is mainly to be attributed to the development of the factory system. Leeds owes no small portion of its prosperity to the enterprise of two of its citizens, who were largely instrumental in introducing improved machinery and processes at a comparatively early period into the two principal manufactures of the town. These were Benjamin Gott, "the foremost woollen manufacturer of Leeds, and the man who helped most to form the character of the improved woollen trade of modern times," and John Marshall, the most celebrated flax-spinner of Leeds, and the founder of a family which still maintains the pre-eminence he gained. Both were of humble origin. Gott was born in 1762, and began work as a humble clerk in a small factory, but was shortly made a partner, and eventually succeeded to the entire management of the establishment. In the "Romance of Trade" it is stated that at the time of Gott's death, in 1840, "about 1,100 workpeople, aided by the most improved machinery, were employed in dyeing, spinning, weaving, fulling, and dressing cloth made of the best Saxony wool" in his factory, which was a model of wise and successful management. "One of Gott's chief merits," says the author of this work, "was the scrupulous regard always shown by him for the men in his employ, and the class to which they belonged. Beginning his enterprise just when the old ways of private work were being in great part superseded by factory labour, he strove hard to perpetuate the spirit of manly independence which had been begotten by the older institutions; and from first to last he encouraged the private workers to bring him their wares, and use him as their agent in disposing of them."

John Marshall, born in 1765, was a shop-boy at the time when he began to devise improvements in spinning machinery, and he was only twenty-three years of age when he started a small mill at Meanwood, near Leeds, with money supplied by two partners. It was in 1787, the year before this mill was built, that John Kendrew and Thomas Porthouse invented flax-spinning machinery, at Darlington; and soon after this similar machinery was introduced and used at Leeds. In 1791 Mr. Marshall removed to Leeds, and built a modest flax-spinning factory at Water Lane, which was enormously extended during the half century that intervened before his death in 1845, and the foundation of the linen trade of the town was laid. By 1821 there were nineteen flax-mills in and near Leeds, with an aggregate of 700 horse-power, containing 36,000 spindles, and producing about 9,000 spindles of yarn per diem, and four of these mills belonged to Mr. Marshall, "forming in extent," says Mr. Warden, "a third of the whole, and equalling Dundee entirely." Little progress was made during the next ten years, there being in 1831 but twenty-four engines at work, representing a total of 705 horse-power. By 1838, however, the number of engines had increased to forty-four, and 6,430 persons were employed in the Leeds linen trade. Twenty-one years later there were in Leeds thirty-seven works devoted to the manufacture of linen, with an aggregate steam-power equal to 1,831 horses, containing 198,076 spindles and 140 power-looms, and employing 9,458 persons.

The flax-mills of the Messrs. Marshall are the largest in the world, and this firm turns out annually a greater number of spindles of yarn and a greater value of yarn and cloth than any other engaged in the trade. Their principal factory is unrivalled alike for extent and completeness. "It is," says Mr. Warden, "132 yards long, 72 yards wide, and 20 feet high. The roof consists of 72 brick arches, supported on as many iron pillars, and secured together by strong iron-work. The brick roof has a thick coating of composition, to prevent the water from coming through, and it is covered with earth, from which has sprung up a beautiful green sward. The glass domes in the roof are each of them 48 feet round, 11 feet 6 inches high, containing 10 tons of glass, in iron window-frames. The total weight of the roof is 4,000 tons. There are four steam-

engines of 100 horse-power, and two of 80 horse-power, and one engine of 7 horse-power which does nothing but blow hot or cold air into the room. The building covers more than two acres of ground, and it is supposed that 80,000 persons might stand in the room. This hall is occupied for spinning and weaving by power, and the whole processes incidental to the trade, subsequent to pickling, are performed in it, the flax going in in bundles and out in bales." The goods made here, as in most of the linen factories of Leeds, are generally of the best description, comprising damasks and the like. Large quantities of linen yarn spun in Leeds are sent to Barnsley, to Ireland, and to France; and canvas and sacking, and other coarse and rough linen goods, are also made to some extent in the town and neighbourhood.

The woollen manufactures of Leeds are chiefly carried on in mills, but the factory system has not entirely supplanted domestic manufacture. There are a number of small masters who employ a few journeymen, besides the members of their own family, and keep from two to four looms at work in their houses. Public mills, on the joint-stock principle, have been erected, which enable the small masters to compete, both as regards price and quality, with the large manufacturers. At one time the small weavers put the wool through all the processes till it was made into undressed cloth in their houses, but they now generally restrict their operations to weaving. In the "Philosophy of Manufactures," Mr. Ure states that the woollen manufactures of Leeds were carried on in 1858 in 128 factories, with an aggregate of 2,924 horse-power, and employing 10,193 persons, whose average weekly earnings amounted to 10s. 6d. each. In the larger mills all the operations are performed, from the breaking of the wool to the finishing of the cloth. The woollen fabrics manufactured in Leeds comprise broadcloths—the best quality produced being now considered equal to the West of England broadcloth—ladies' cloths, kerseys, swan's-downs, etc.

The iron-works and machine shops of Leeds are very extensive, and in 1858 employed 10,909 persons, who during the year received £560,092 in wages. There were at the same date about 3,000 ironstone and coal miners occupied in the district, and 900 persons were at work in the clay-pipe and brick fields. The most important of the minor industries of the town are the silk manufactory, which in 1858 gave occupation to 550 operatives; the manufacture of leather, which then employed 2,000 persons; the chemical works, the earthenware works, and the glass-works, which employ together upwards of 1,600 persons.

PRINCIPLES OF DESIGN.—XVIII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS (*continued*).

In my last chapter I drew attention to the principle on which all carpet patterns should be constructed as distinctive from wall patterns, and in order to impress the necessity of giving a radiating basis to the ornaments placed upon carpets, and not a bilateral structure, I made reference to the principle of plant growth, where we notice that all plants when viewed as floor ornaments, when viewed from above, are of a radiating character; whereas if they are seen as wall or vertical ornaments, they are either radiating or bilateral: this is a necessity of a carpet pattern, that it have a radiating structure, or, in other words, that it point in more than two directions.

Man naturally accustomed to tread on grass when brought into a state of civilisation, seeks some covering for his floor which shall be softer to the tread and richer in colour than stone or brick. And in our northern climate he seeks also warmth; hence he chooses not a mere matting, or lattice of reeds, but a covering such as shall satisfy these requirements.

In early times our floors appear to have been strewn with sand—a custom still lingering in some country districts; then came the habit of strewing reeds over the floor, and, on the part of the opulent, sweet scented reeds (*Acorus calamus*). And it is curious to notice, in connection with this subject, that one of the charges brought by Henry VIII. against Cardinal Wolsey was that of extravagance in the use of sweet reeds. This use of reeds was succeeded by the employment of mats of simple appearance, formed of a kind of grass, and these by the introduction of wool mats, which, at first, were chiefly imported, but afterwards manufactured in our own country. The wool mats were in their turn replaced by carpets, which gradually increased in size till their proportions became such as to cover the entire floor on which they were placed.

This brief history brings us to notice what is required of a carpet: thus, it should be soft in texture, rich in appearance, and of "bloomy" effect.

We may add to these requirements by saying that a carpet should also be a suitable background to all works of furniture or other objects placed upon it, and that in character it should accord with the objects with which it is associated in any particular apartment.

Considering more fully these requirements, we notice that a carpet should be soft. This is very desirable, for softness gives a sense of comfort, and with softness is generally combined durability; but softness can scarcely be regarded as an art-quality. Yet as the art which an object bears is more leniently viewed when the fitness of the object to the purpose for which it is intended is apparent, we may safely regard softness as a very desirable quality of a carpet.

The Eastern carpets are pre-eminent in this quality of softness, and of English-made carpets "Brussels" and tapestry are the least satisfactory in this way as usually made, they having a hard "backing." A kind of Brussels carpeting with a soft back has recently been brought out, but at present it is not general in the trade. If the carpet employed in any apartment as a floor covering is harsh in character, it is desirable to place soft felt under it (felt for this purpose can be got at carpet warehouses), or evenly spread soft hay, for by so doing the wear of the fabric will be greatly increased, and the pleasure of walking on it will also be correspondingly greater.

The next quality of a carpet is richness. No carpet is satisfactory which is "washy" or faded in appearance. There must be "depth" of effect, a "fulness" of art quality. Hangings may be delicate, wall-decorations soft in tint, but a carpet must be rich and "full" in effect.

But this richness must be of singular character, for the most desirable effect which a carpet can present is that of a glowing neutral bloom.

I hope that my language does not appear mystical to the general reader or young student. To the ornamentist I think it will be intelligible. What I wish to say is that the effect should be glowing, or radiant, or bright, as opposed to dull, quiet, or heavy; that it should be such as results from the use of a predominance of bright and warm colours, rather than of cold and neutral hues; that it should be neutral, inasmuch as it should not present large masses of positive colour, but should have an equality of rich harmonious colours throughout; that it should be "bloomy," or have the effect of a garden full of flowers, or better, of the slope of a Swiss Alp, where the flowers combine to form one vast harmonious "glow" of colour. This is the effect which a carpet should present, yet it should never present flowers, imitatively rendered, as its ornamentation. Such imitative renderings are not to be produced by the ornamentist; they must come from the pictorial artist, for they are pictures. They cannot form suitable backgrounds to furniture and living objects, for they are positive, and not neutral, in their general effect. A picture, also, will not bear repetition: whoever heard of one person having two copies of the same picture in one room? Yet a pictorial group of flowers may be seen repeated many times over a floor, which is very objectionable. The effect to be produced is that of a rich "colour bloom;" but the skilled ornamentist will achieve this without violating any laws of fitness, and will gently and delicately hint at the beauty of a profusion of blossom through his tenderly-formed pattern.

Yet a carpet must be neutral in its general effect, as it is the background on which objects rest. Neutrality of effect is of two kinds. Large masses of tertiary or neutral colours will achieve its production, so also will the juxtaposition of the primary colours in small quantities, either alone, or with the secondary colours, and black or white; but there will be this difference between the two effects—that produced by low-toned colours will be simply neutral, while that produced by the primary colours will be "bloomy" as well as neutral, and if yellows and reds slightly predominate in the intermingling of colours, the effect will be glowing or radiant.

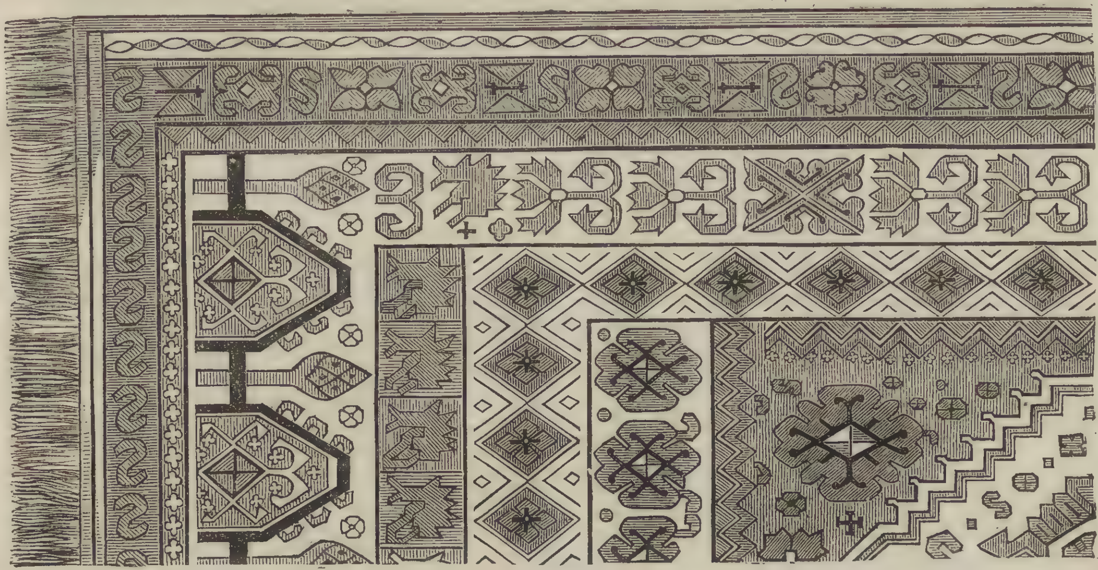


Fig. 64.

Fig. 65.

The radiant, or glowing, bloomy neutrality of effect is that which it is most desirable that a carpet should present.

This effect is rarely produced in English carpets, owing either to the want of skill on the part of the ornamentist, who is unable to produce such works; the want of judgment on the part of the manufacturer, whereby he fails to produce such patterns; or the want of taste on the part of the consumer, owing to which he buys works of a more vulgar character. I designed six carpets for Messrs. Crossley and Sons, of Halifax, which were afterwards shown in the International Exhibition at South Kensington, in which I sought to realise as much of this effect as I could with six colours—the number to which I was limited by the conditions of manufacture; and fortunately these appeared to command a large sale, and to set, to a certain extent, a fashion in carpets; but those who wish to study these bloomy effects in their more perfect forms, must do so in the carpets of India, Persia, Smyrna, and Morocco, but especially in the Indian rugs.

Some of the carpets from India are perfect marvels of colour, harmony, and of radiant bloom. They appear to glow as a bed of flowers in the sunshine, and yet they are neutral in their general effect, and when placed in an apartment do not usurp a primary place, as does any pictorially-treated pattern.

This "bloom" was seen to perfection in one or two silk rugs which were shown at the International Exhibition of 1862 in London, and it was not much less apparent in some of the carpets from India shown in the Paris Exhibition of 1867, the most lovely of which was purchased by John Lewis, Esq., now a partner in the firm of Messrs. Crossley and Sons. Most Indian carpets have this colour-bloom to some extent, and few are unworthy of careful study.

Persian carpets (Fig. 64) are also models of what carpets should be; they are less radiant than many of the Indian works, but are almost more mingled in colour-effect. In pattern, many of the Indian and Persian carpets are identical, being traditional, yet in colour they differ, and both are worthy of the most careful consideration.

The Morocco carpets (Fig. 65) differ again from both those of India and Persia, and even to a greater degree than the Persian carpets differ from the Indian. In these there is often a prevalence of soft yellows and juicy yellow-greens, intermingled with reds, blues, and grey-whites, in such a manner as to produce a most harmonious and artistic effect. To the young student, and to any who may desire to cultivate his taste in respect to such matters, I say, Study the carpets of India, Persia, and Morocco most carefully.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XV.—BENJAMIN HUNTSMAN.

BY JAMES GRANT.

In a work like The Technical Educator, the inventor of cast steel could scarcely be omitted. Benjamin Huntsman, prior to whose time most of the steel used in England and Scotland came from Germany, Flanders, or Sweden, was born in Lincolnshire in the year 1704. Being of a clever and ingenious turn he was bred to mechanics, and, as a lad, became chiefly famous as a repairer of clocks; thus eventually he opened a shop in Doncaster, where he was deemed the principal maker and mender of clocks in West Yorkshire. "He also undertook various other kinds of metal work," to quote Mr. Smiles, "such as the making and repairing of locks, smoke-jacks, roasting-jacks, and other articles requiring mechanical skill. He was remarkably shrewd, observant, thoughtful, and practical—so much so, that he came to be regarded as the 'wise man' of his neighbourhood, and was not only consulted as to the repairs of machinery, but also of the human frame. He practised surgery with dexterity, though after an empirical fashion, and was held in especial esteem as an oculist."

It would seem that, for his medical advice, he never took fees in return. In West Yorkshire, there are still in existence several of the clocks that were made by Benjamin Huntsman, and one of these possessed by his descendants has a pendulum of pure cast steel. In the pursuit of his multifarious mechanical callings, this ingenious man invented several new or highly-improved tools; but the inferior quality of the common German steel with which he wrought, he considered a serious obstruction, and he was thus induced to consider the means of producing a better and purer material than that which came from the Continent. At Doncaster he had commenced, in a small way, his first experiments, as the steel pendulum referred to serves to show; but in the year 1740 he removed to the vicinity of Sheffield, as he had a difficulty in procuring a sufficient supply of fuel for smelting purposes in the former town.

At the little village of Handsworth, a few miles south of Sheffield, he now began to pursue secretly his experiments, of which no memoranda or record have been preserved, neither are there any of his modes of investigation. But the progress of the work must have cost him much care, thought, and consideration, as he was totally without those appliances which were requisite, and which have been the gradual development of later times. Not only had Huntsman to discover the fuel and flux proper for his purpose, but he had to construct a furnace, and make a crucible such "as should sustain a heat more intense than any then known in metallurgy," in England at least. All those requisites which are now familiar in the process of smelting—hoops, wedges, and ingot-moulds—were as yet in the womb of the future.

Many years would seem to have been passed in unsuccessful experiments, before he obtained the purity of metal he coveted; and, curiously enough, he would appear to have hidden, by burying in the earth, many hundred-weights of steel in the manufacture of which he had failed from various causes, such as bad fluxes, imperfect melting, the bursting of crucibles, and other casualties; for long after he had passed away, these relics of his numerous failures were dug up from time to time in the vicinity of Handsworth. Cast steel is iron in its very highest state of perfection—the iron being united to carbon with a small portion of oxygen while in an elastic state; but the coarse crude or pig-iron consists of the metal combined with carbon in a material state. The great merits of cast steel are its fineness of grain, its perfect cohesion, durability, and capacity to receive a keen edge, and hence its value in the manufacture of all manner of tools, and all the implements of peace and war.

The perseverance of Huntsman was rewarded at last, and his great invention, one of the highest rank, and one which greatly contributed to forward the industrial and commercial supremacy of the British Isles, was completely perfected.

The process of making cast steel, as invented by Benjamin Huntsman, may be thus summarily described:—The melting is conducted in clay pots or crucibles, manufactured for the purpose, capable of holding about thirty-four pounds each. Ten or twelve of such crucibles are placed in a melting-furnace, similar to that used by brass-founders; and when the furnace and pots are at a white heat, to which they are raised by a coke fire, they are charged with bar-steel, reduced to a certain degree of hardness, and broken into pieces of about one pound each. When the pots are all thus charged with steel, lids are placed over them, the furnace is filled with coke, and the cover put down. Under the intense heat to which the metal is exposed, it undergoes an apparent ebullition. When the furnace requires feeding, the workmen take the opportunity of lifting the lid of each crucible, and judging how far the process has advanced. After about three hours' exposure to the heat, the metal is ready for turning. The completion of the melting process is known by the subsidence of all ebullition, and by the clear surface of the melted metal, which is of a dazzling brilliancy like the sun when looked at with the naked eye on a clear day. The pots are then lifted out of their place, and the liquid steel is poured into ingots of the shape and size required. The pots are replaced, filled again, and the process is repeated; the red-hot pots thus serving for three successive charges, after which they are rejected as useless.

More than a century has passed since the invaluable discovery made by Benjamin Huntsman; yet the kind of fuel to which he resorted, coke, and the furnaces and crucibles he adopted for smelting—all the suggestions of his own mind—are greatly similar to those in use at the present time, and no manufacturer has, it is said, been able to surpass the quality of the steel he produced.

Finding now that the boasted metal of all other foreign markets had been surpassed, Huntsman saw that cast steel

could be turned to other purposes than watch-springs and the pendulums of clocks. He offered his new metal to the cutlers of Sheffield for the manufacture of knives, tools, swords, etc.; but, one and all, they ignorantly and perversely declined to work with a metal so much harder and denser than any to which they had been accustomed. Mortified and foiled at home, Huntsman had to turn his attention to foreign markets, and soon found that the demand was so great that he could scarcely overtake the supply. This was chiefly in France, and thus, though for a time only, the merit of applying cast steel as now used belongs to the French. They were bold enough to claim the whole invention as being that of a native of France, and such continued to be long the popular fallacy, till M. Le Play, Professor of Metallurgy in the Royal School of Mines in France, after making long and careful investigations, and weighing all the evidence on the subject, arrived at the conclusion that the invention fairly belongs to Huntsman and to no French subject.

M. Le Play also showed, in his Report to the French Government, the systematic neglect which men of Huntsman's class and inventive genius have too generally received in England, and the much greater esteem in which they are held by scientific foreigners.

The Sheffield manufacturers soon saw the folly of which they had been guilty when Huntsman had fairly established his business in France, from whence his steel obtained a reputation over all the Continent, and even among the sword-cutlers of Toledo; and seeing the injury that would be done to their own trade if foreign goods were thus preferred by British as well as Continental consumers, they were arrogant and illiberal enough to send a deputation to Sir George Savile, M.P. for the county of York, requesting him to use parliamentary influence to prohibit the exporting of cast steel. Perceiving that they were inspired by self-interest only, he curtly declined, and meanwhile Huntsman had pressing offers from certain hardware manufacturers in Birmingham to remove his business and his furnaces there, to which he did not accede; and as the cutlers in Sheffield speedily found that if they would keep the French out of the market they must use the steel of Huntsman, his trade multiplied rapidly at home as well as abroad.

Innumerable efforts were made by the Sheffield cutlers to elicit from him the secret he possessed, for he had no patent to protect him; and hence a kind of mystery accompanied the process of his smelting. All strangers were sedulously excluded from his works; the whole of the steel was melted there in the night, and all his men were sworn to preserve perfect secrecy. Hence the most absurd rumours soon became current; among others, that his process involved the infusion of broken bottles. He used only the best bar steel, and it came from Danemora (thirty-five miles from Upsala in Sweden), where iron mines have been constantly wrought since the fifteenth century, and the metal produced was esteemed as the best in Europe. After being brought from the mines, it was smelted by charcoal in the forges of Osterby, and prepared for exportation—the exportation of unsmelted ore being utterly forbidden by the Swedish government, then at least. Five hours formed the time requisite for Huntsman to convert the Danemora metal into pure cast steel.

An envious rival and iron-founder named Walker, who resided at Greenside, near Sheffield, is said to have been the first person who succeeded, by a pitiful deception, in copying and pirating the unprotected secret of Huntsman. Disguised as a beggar, and feigning abject misery and distress, he appeared at the foundry-door late one night, when the snow-flakes were falling fast, and the red glare of Huntsman's furnaces shed a cheerful glow over all the neighbourhood. Shivering with cold and apparent hunger, he moved the workmen's hearts to let him enter and warm himself in the works; and he was accordingly permitted to take up his quarters there for the night, lest he might perish if shelter were denied him.

"A careful scrutiny," writes the author of "Useful Metals and their Alloys," "would soon have discovered little real sleep in the drowsiness which seemed to overtake the tattered stranger; for he eagerly watched every movement of the workmen while they went through the operations of the newly-discovered process. He observed, first of all, that bars of blistered steel were broken into small pieces, two or three inches in length, and placed in crucibles of fire-clay. When nearly full, a little green glass, broken into fragments, was spread over the top, and the whole covered with a closely-fitting cover. The crucibles were then placed in a furnace previously prepared for them, and after a lapse of from three to four hours, during which they were examined from time to time to see that the metal was thoroughly melted and incorporated, the workmen proceeded to lift the crucible from its place on the furnace by means of tongs, and its molten contents, blazing, sparkling, and spurting, were poured into a mould of cast iron previously prepared; here it was suffered to cool, while the crucibles were again filled and the process repeated. When cool, the mould was unscrewed, and a bar of pure cast steel presented itself, only requiring the aid of the hammermen to form a finished bar of cast steel. How the unauthorised spectator of these secret operations effected his escape without detection, tradition does not say; but it tells us that before many months had passed the Huntsman manufactory was *not* the only one where cast steel was produced."

Despite this unscrupulous opposition, the demand for Huntsman's steel increased steadily; and thus, for the purpose of having a greater range for his works and speculations, in 1770 he removed to the village named Attercliffe-with-Darnal, near Sheffield, where he had built a large and commodious foundry, with furnaces and all requisite appliances. The Royal Society of London wished to elect him as a member, in consequence of the great merit attached to his invention of cast steel; but as this would have drawn him from the seclusion he preferred, he declined the proffered honour; moreover, he believed that to have such initials after his name as F.R.S. would be opposed to the principles of the religious body of which he was a zealous member—the Society of Friends. For six years he continued to flourish, "making steel and practising benevolence," till the year 1775, when he died at the age of seventy-two, and was interred in the churchyard of Attercliffe, where a grave-stone with an inscription records the facts of his birth, death, and the brief history of his great invention.

This grave was visited by M. Le Play, the learned Professor of Metallurgy in the Royal School of Mines in France, in his enthusiasm and admiration for this humble mechanic, whose steady perseverance had enabled him to overcome all the difficulties he experienced in perfecting his great invention and discovery. The Huntsman mark on steel became a trade-mark known throughout the civilised world. His name is well-nigh forgotten in England now; but, as Sir Henry Englefield says, "were public benefactors to be allowed to pass away, like mere hewers of wood and drawers of water, without commemoration, genius and enterprise would be deprived of their most coveted distinction."

While on the subject of iron and steel, it may be interesting to mention that nowhere were they more early prized than in the East. Even in the 57th chapter of the Koran, Mohammed says that God sent down with the apostles the Scriptures, the balance, and *iron* "wherein is the mighty strength for war;" and Al Zamakhshari adds the Arab tradition, that Adam is said to have brought down with him from Paradise *five* things made of iron—viz., an anvil, a pair of tongs, two hammers, a greater and a lesser, and a needle!

TECHNICAL DRAWING.—XL.

DRAWING FOR STONEMASONS.

THE ARCH: VARIOUS FORMS OF ARCHES AND VAULTS.

An arch in masonry is a part of a building suspended over a given space, supported only at the extremities, and concave towards the plan. The general history and principles of construction of arches have been given in "Building Construction;" only such portions of what has there been said are repeated as are necessary for the further investigation of the subject; and, for the rest, the student is referred to the lessons alluded to.

The supports of an arch are called the *spring walls*.

The whole of the under surface of the arch opposite to the plan is called the *intrados*, and the upper side is termed the *extrados*.

The boundary line or lines of the intrados, or those common to the supports and the intrados, are called *springing lines* of an arch.

A line extending from any point in the springing line on the

one side of the arch, to the springing line on the opposite side, is called the *chord* or *span* of the arch.

If a vertical plane be supposed to be contained by the span and the intrados of the arch, it is called the *section of the hollow* of the arch.

The vertical line drawn on the section from the middle of the spanning line to the intrados is called the *height* of the arch, as also the middle line of the arch, and the part of the arch at the upper extremity of this line is called the *crown* of the arch.

The curved parts on the top of the section between the crown and either extremity of the spanning line are called the *haunches* or flanks of the arch.

Arches are variously named, according to the geometrical figure by means of which they are formed, as *semi-circular*, *elliptical*, *cycloidal*, *catenarian*, *parabolical*, etc.: these, as well as the *horseshoe*, *stilted*, *composite*, and *pointed*, together with the method of constructing them, have been given in the lessons in "Building Construction."

When the extremities of an arch rise from supports at unequal heights, the arch is called *rampant*.

When the upper line or side of an arch is parallel to the under line or side, it is called an *extradossed* or *concentric* arch (Fig. 363).

When the outer side of the curve is drawn from another centre, it is called an *eccentric* extrados (Fig. 364).

The term *arch* is frequently confounded with *vault;* but the distinction we shall adopt here is based on the degree of depth, an arch being a structure of no very great depth from one side to the other, whilst a vault may be unlimited. Thus we say "an *arch* in a wall," but "a *vaulted apartment* or cellar," so that a vault is an extended arch. Practically, every vault is an arch, but every arch is not a vault.

A vault is *cylindric* when its form is that of a cylinder, never greater than the half when the axis is in the same plane with the springing of the arch. It is also termed *barrel* or *wagon-headed.*

A vault in *full centre* is that which is formed of the surface of a semi-cylinder.

A vault is said to be *surmounted*, or *surhausse*, when it is formed by the portion of any curve where the height is greater than half the span.

A vault is termed *surbaise* when the height at the crown is less than half the width of the springing.

A *rampant* vault is one the springing of which is not parallel to the horizon, as in many staircases descending into cellars.

Conic vaults are, as their name implies, of the form of a cone. They may be of three kinds, according to the disposition of the axis—viz., parallel, perpendicular, or oblique to the horizon.

Spherical vaults are usually called *domes.* All domes are, however, not spherical, since they may spring from a polygonal, circular, or elliptic plan, presenting a convex surface on the outside, and a concavity within, so that every horizontal section may be of a similar but different-sized figure, and have a common vertical axis.

The word *dome* is generally applied to the external part, and *cupola* to the inner part.

It is believed that the term is derived from the Latin word *domus*, a house. The Germans call it *dom*, and the Italians *duomo*, and apply the name to the principal church of a city, although the building may not have any dome.

An *annular vault* is one of which the plan is contained between two concentric circles; its generating section may either be that of a pointed arch or of a semicircle, or, indeed, of any other curve.

A *simple* vault is one which is constructed of the surface of some regular solid, around one axis or centre.

A *compound vault* is one which is made up of more than one surface of the same solid or of two different solids, such as would be formed by two cylinders or spheres penetrating each other.

Cylindro-cylindric vaults are such as are formed of the surfaces of two unequal cylinders.

Groined vaults rise in their surfaces to the same height as two equal cylinders, or a cylinder with a cylindroid. Several of these arches or vaults will form the subjects of future lessons.

We now proceed to give the method of drawing the examples in Figs. 363, 364, 365.

Fig. 363 is the elevation of a concentric semi-circular arch. The student is reminded that in this all the joints must be radii of the circle of which the arch is one-half, and that the separate stones of which the arch is built are called *voussoirs*, the middle one being the *keystone*, and the two lowest—that is, those resting immediately on the abutments or piers—being termed *springers.*

Fig. 364.—This example shows a section of a semi-circular vault with an eccentric extrados. This system is much more solid than that shown in Fig. 363, whilst the depth at the crown is the same.

To draw the eccentric arch, the intrados A B C having been described, and the height of the extrados having been fixed at D, set off from B two-thirds, three-fourths, or even the whole length, A C—viz., to E—then, with radius E D, describe the extrados F D G. The divisions of the voussoirs must be set off on the intrados, the joints converging to the centre O.

Fig. 365 shows the manner of terminating the arch by horizontal and vertical lines. These are drawn from the points where the radii cut the extrados. When it is desired that the horizontal lines should coincide with the courses of stone, the horizontal joints are continued until they cut the radii; this is shown in the right side of the example. This method is not so good as that shown on the left side, where the pressure is borne uniformly by the whole joint; for it will be seen that an interior angle has to be cut in the under surface, into which an external angle cut in the stone beneath must fit; but if this angle is not cut with the utmost accuracy, the construction would be compromised by the transverse cracking of the stones when under pressure.

Fig. 366 is an arch formed by the segment of a circle. This method is frequently employed in the construction of bridges. It will be seen that the intrados having been divided into the required number of parts, the joints for the voussoirs, which are radii of the arc, are carried up, and are intersected in groups by the horizontal courses of the stonework.

Fig. 367 shows a semi-elliptical arch, the curve of which may be constructed in any of the various methods shown in "Practical Geometry applied to Linear Drawing." To find the direction of the joints, which must be perpendicular to the curve, divide the intrados into the required number of equal parts, and from the foci F and F draw lines to each of these points, as shown at A; bisect the angle thus formed, the bisecting line A C will be one of the joints required.

It will be seen this is an illustration of a surbaised vault, the height at the crown being less than half the width of the springing.

Fig. 368.—This is a rampant arch. To draw the intrados of this, the height of the imposts A and B being given, draw the line A B joining the imposts, and bisect it in C. At C draw a vertical line, and make C D equal to C B. From D draw a line at right angles to A B, intersecting horizontal lines drawn at A and B in E and F, which will be the centres required.

Draw the arc D B with the radius E D, and the arc D A with the radius F D.

Divide the intrados into the required number of equal parts, and the joints will be radii of the arc in which they are contained.

Platbands.—A platband is any flat square moulding whose height much exceeds its projecture. Such are the faces, or "fasciæ," of an architrave, and the platbands of the modillions of a cornice.

The platband of a window or door is used for the lintel, where that is made square or not much arched. These platbands are usually crossed with bands of iron when they have a great bearing; but it is much better to ease them by building discharging arches over them. The uses of both lintels and discharging arches have been explained in lessons in "Building Construction."

Fig. 369.—The whole platband of a window or door, which is simply a straight arch, must form a trapezium, A B C D, of which the upper line, or extrados, D C is, of course, the longest side; and each of the stones should be of the trapezium or wedge-like form, so that neither of them may slip between the others.

To accomplish this, divide the intrados A B into an uneven number of equal parts. Construct on A B the equilateral triangle (which form is usually adopted) A B O. Draw the line from O

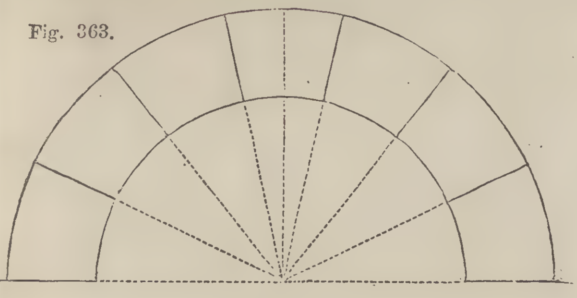


Fig. 363.

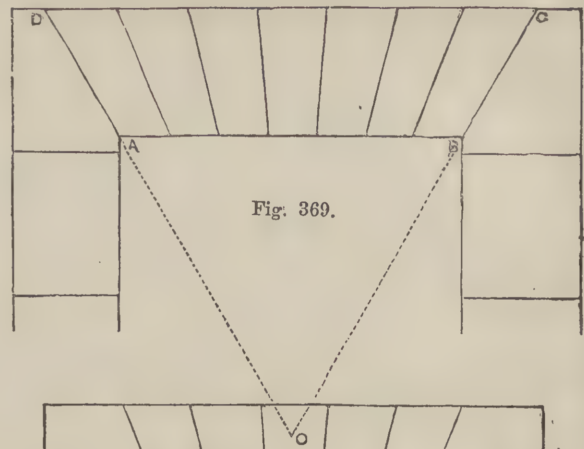


Fig. 369.

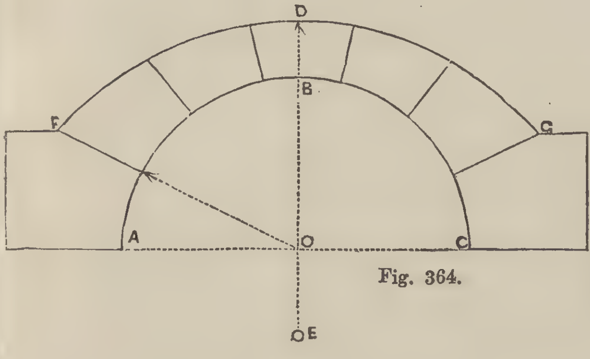


Fig. 364.

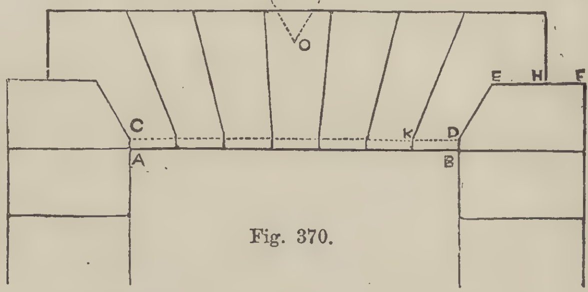


Fig. 370.

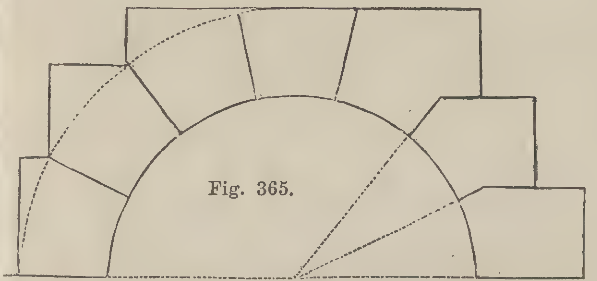


Fig. 365.

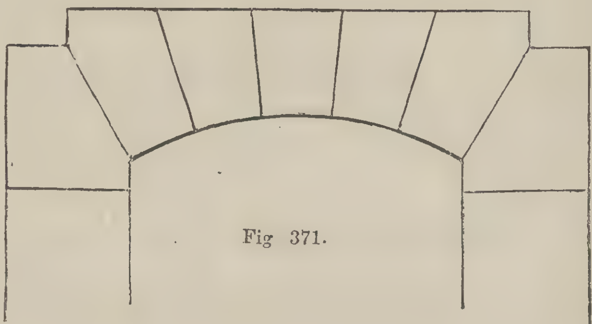


Fig 371.

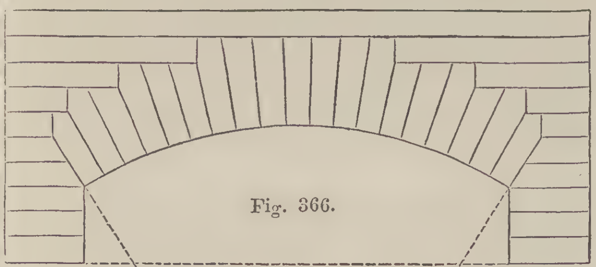


Fig. 366.

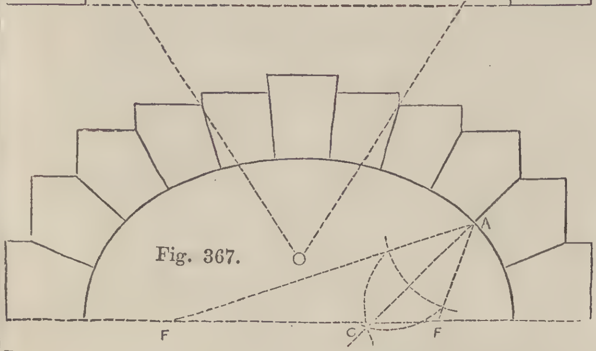
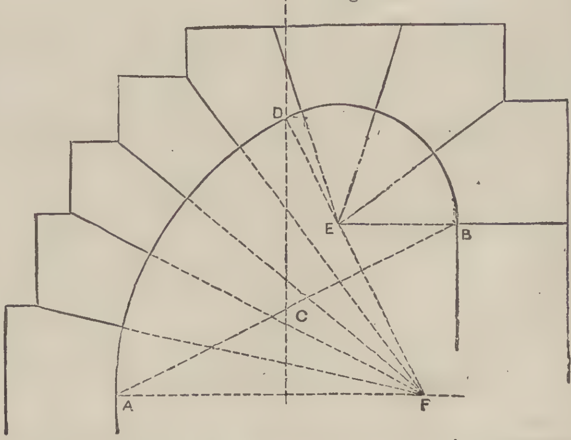


Fig. 367.

Fig. 368.



through the points in the intrados, cutting the extrados. These lines will give the keystone and the voussoirs.

Fig. 370.—In this figure another method is shown which materially adds to the strength of the arch. To construct this form, divide the intrados as before into an uneven number of equal parts; produce the sides of the piers beyond A and B, and draw the line C D. From the points of division draw perpendiculars, as K, and from D, K, etc., draw the joints. It will be observed that the pressure is thus brought to be as much as possible downward instead of outward, since the main bearing of the platband is on the horizontal top of the pier E F.

Fig. 371 is another example for drawing a similar subject, in which increased strength is given by increasing the depth of the voussoirs as they approach the keystone. The method of drawing this subject will be understood from the previous examples.

NOTABLE INVENTIONS AND INVENTORS.

XVIII.—THE DIVING-BELL (*concluded*).

BY JOHN TIMBS.

DR. HALLEY also invented an apparatus by which a man might leave the diving-bell and walk about at the bottom of the sea, his head being covered by a heavy leathern cap, like a small diving-bell, supplied with air by a flexible tube extending from the large bell. The diver was to coil this tube round his arm, and unwind it as he left the bell; and to use it as a clue to direct him to the bell in returning. The modern invention of water-proof india-rubber cloth water-tight tubes is well known. By these tubes, so long as the head-covering or helmet is above the level of the water, it will be kept full of air; and in case of having to stoop below that level, as in getting out of or into the bell, the diver has only to close a valve, by which the air in the helmet is prevented from returning into the bell. The front of the helmet is glazed, and the diver was enabled to walk by means of a weighted girdle and weighted clogs. Aquatic armour supplied with air from above, or carrying a store in its cavities sufficient to last for the time the diver intends to remain submerged, has been little used. As early as 1715, a diving apparatus, consisting of a case for enclosing the person, with the arms protruding in flexible sleeves, was contrived and used for many years by one John Lethbridge, of Newton Abbot, Devon. This apparatus was supplied with air by flexible pipes. A similar machine, contrived by Mr. Rowe, in 1753, was lowered by tackle, like a diving-bell. At Newton Bushel, Devon, an ingenious person contrived a large strong leather water-tight case, to hold half a hogshead of air, and adapted to the legs and arms, with a glass in front, so that the wearer could walk about easily at the bottom of the sea, examine a wrecked vessel, and deliver out the salvage. The inventors of this apparatus used it forty years, and thereby acquired a large fortune.

Among the early projects for submarine navigation should be mentioned Drebell's vessel to be rowed under water, which was tried in the Thames by order of James I., and carried twelve rowers besides passengers. It is described by the Hon. Robert Boyle, who states the chief secret to be "the composition of a liquid that would speedily restore to the troubled air such a proportion of vital parts as would make it again for a good while fit for respiration." But the composition of this liquid for enabling the same air to be used again and again was never made public.

Bishop Wilkins, in 1648, devised an "Ark for Submarine Navigation," in which he states "all kinds of arts and manufactures may be exercised. The observations made by it may be both written and (if need were) printed here likewise; several colonies may thus inhabit it, having their children born and bred up without the knowledge of land, who could not choose but be amazed with strange conceits upon the discovery of this upper world." The bishop adds: "I am not able to judge what other advantages there may be suggested, or whether experiments would fully answer to these notional conjectures." In 1774 a projector named Day lost his life in an experiment to descend in Plymouth Sound, with a vessel of about fifty tons burden, which he thought he could have caused to rise after a lapse of several hours. A long account of this failure was published. The machine by Bushnell, of Connecticut in 1771-5, for submarine navigation, was very successful; his vessel was propelled by screws. Mr. Babbage long since laid down a plan of a vessel for submarine navigation, in which he proposed to use oxygen, condensed in store vessels, to replenish the air, and to absorb the carbonic acid produced by respiration, either by cream of lime, or by a strong solution of ammonia. The principle of Payerne's diving-bell is the production of pure air fit for the respiration of man, and for supporting flame without communication with the external air. Deane's diving apparatus has been much used in submarine descents for the purpose of exploring various wrecks. In 1834, equipped in his diving dress, Deane descended by the ladder from the *Mary*, in seventy-two feet depth of water, to the wreck of the *Royal George*, the condition of which he represented, and slung and sent up one of the vessel's brass guns, a twenty-four pounder; by the same means six other of her guns were removed. Deane likewise attended Walker and Burgess, the engineers, and frequently descended to the foundations of old Blackfriars Bridge, and examined the work in progress. Heinke's diving apparatus was employed in removing the foundations of old Westminster Bridge, for five years, without any accident.

In the year 1838 the diving-bell became the paramount attraction of the Polytechnic Institution in Regent Street. It is constructed of cast iron, weighs three tons, is five feet in height, and five feet four inches in diameter at the mouth. It is lighted by twelve openings, of thick plate-glass, secured by brass frames to the bell. This is suspended by a massive chain to a large swing crane, with powerful crab, the windlass of which is grooved spirally; the chain passes over four times into a well beneath, and to it are suspended the compensation weights, which, by acting upon the spiral shaft, accurately counterpoise the bell at all depths. It is supplied by two powerful pumps, of 8-inch cylinder, with air conveyed by leather hose lined with caoutchouc cloth, and fitted inside with spiral wire. Nearly round the inside of the bell extends the seat; and on the side is affixed a knocker, under which is painted—"More air: knock once. Less air: knock twice. Pull up: knock three times." Provision is made for adding weight to the bell; and outside six massive vertical straps meet on the crown in a double ring, by which the bell is suspended from the crane. The four or five divers (visitors) having taken their seats, the air is pumped through the hose screwed into the crown, the bell is moved over the tank of water by the crane, let down within two feet of the bottom, and then drawn up. Each person pays one shilling for the descent, which has been known to yield the sum of £1,000 in one year. The cost of the bell was about £400.

Sir George Head, in his popular "Home Tour," has well described a pair of operative divers, whom he saw in the Hull docks. Sir George was passing as the workmen were raising the diving-bell, when, as the bell was raised very slowly, he looked within it, by stooping, at the moment its side was above the gunwale of the lighter. The pair of divers had been under water two hours. Their sensations on going down (before a man was used to it) produced a feeling as if the ears were bursting; on the bell first dipping, they were in the habit of holding their noses, at the same time of breathing as gently as possible, and thus they prevented any disagreeable effect. "Had there been anything extraordinary to see below," says Sir George, "I should have asked permission to go down; but the water was by no means clear, and the muddy bottom of the docks was not a sufficient recompense for the disagreeable sensation. Two men descend at a time, and four pump the air into the bell through the leathern hose; the bell is nearly a square, or rather, an oblong vessel of cast iron, with the two bull's-eye lights at the top, which lights are fortified within by a lattice of strong iron wire, sufficient to resist an accidental blow of a crowbar or other casualty." Sir George concludes: "Notwithstanding the great improvements made in diving-bells since this invention, after all precautions, a man in a diving-bell is certainly in a state of awful dependence upon human aid; in case of the slightest accident to the air-pump, or even a single stitch of the leathern hose giving way, long before the ponderous vessel could be raised to the surface, life must be extinct." Nevertheless, Sir George had previously remarked, "the service cannot be formidable, as the extra pay is only one shilling per day."

MINING AND QUARRYING.—IX.

BY GEORGE GLADSTONE, F.C.S.

IRON.

MODE OF SMELTING ORE—THE FUEL—THE FLUX—TEMPERATURE OF THE FURNACE—DIFFERENT QUALITIES OF PIG-IRON—IRON FOUNDING.

In the present paper we shall describe the method by which the smelting of the ore is carried on.

As a preliminary step the furnace has first to be put into blast, a process occupying upon the old plan a fortnight to three weeks, but now somewhat reduced. The building must in any case be heated up very gradually, because a too sudden driving off of any moisture, and too rapid an expansion of the materials of which it is built, would weaken the whole edifice. The modern plan is to fill the hearth with wood, cover that with five or six tons of coke, and then alternate layers of limestone, coke, and a little ore, until the furnace is about one-third full. The wood is then kindled, and the fire gradually makes its way upwards. As soon as it has extended through the whole mass, more materials are thrown in, the quantity of ore being gradually increased, until the furnace is full. When the whole is incandescent, the blast is turned on gently for a day or two, and then to its full strength, when the "blowing in" is completed.

When regularly in blast, the charge consists of three articles only—the ore, the fuel, and the flux. No one rule can be laid down as to the proportions in which they should be used, because this depends upon a variety of considerations, the most important of which is naturally the per-centage of metal contained in the ore itself: one-eighth of flux, and three-eighths of fuel, to four-eighths of calcined ore may be taken as approximate proportions; but how greatly these vary may be illustrated by the fact that the red hæmatites scarcely need any flux at all. There is, however, one rule of uniform application; that the furnace must be kept full. The charge is thrown in through the door in the chimney, or into the hopper of a closed furnace, on a level with the gallery, relays of workmen being constantly employed in keeping up the supply both by day and night. The furnace is tapped by driving a crowbar through the tap-hole below the dam-plate at the bottom of the hearth, so as to remove the sand, when the molten iron runs out. Before the tapping the blast is stopped; and as soon as the liquid iron has ceased to flow the tap-hole is closed with some fresh sand, the blast is turned on again, and the smelting proceeds as before.

The fuel is now almost always applied in the form of coke. It is generally made on the spot, and for this purpose the coal employed should be as free as possible from sulphur, and should leave but little ash. The cokes made from the bituminous coals of the north of England contain on an average about 0·60 per cent. of sulphur, some portion having already been volatilised and driven off in the process of coking. In the neighbourhood of Swansea anthracite coal is used in some works instead of coke. It has the advantage of being very free from sulphur, but it is difficult to work with, as it will not burn except at a very intense heat, often exceeding even that of a blast-furnace. Some of the anthracites will indeed scarcely burn at all; they decrepitate and form a fine powder, which collects at the bottom and becomes a regular nuisance by choking up the furnace and impeding the draught. For these reasons anthracite is but little used in this country, though in the United States it is the favourite coal for all such purposes, the American anthracite burning far more freely. In England bituminous coal is seldom used alone, though not unfrequently a small portion of it is mixed with the coke. In Scotland it is more common to smelt the black-band ironstones with the hard splint coal in its natural condition. In some few furnaces, especially where the best red hæmatites are smelted without intermixture of any inferior ores, charcoal is still used; a very superior iron is the result, which fetches a high price.

Limestone is almost universally employed as the flux. It seems to be providentially supplied for the purpose, the Carboniferous limestone which is associated with the coal and iron beds of that series being very pure, and therefore suitable for the smelter. The three articles, the ore, the fuel, and the flux, are therefore generally found in Nature in juxtaposition; but the ironmaster is really still further favoured, for the same geological formation supplies also the millstone grit, which is the best stone that can be found for building blast-furnaces, and the fire-clay from which the fire-bricks are made. The whole of the important articles required by the smelter, both for the fixed plant and the current work, may therefore be obtained upon the spot. At Dudley, the Silurian limestones lie in immediate contact with the coal and iron bearing strata; and the Silurian hills being favourably situated for working, they have supplied the flux for the neighbouring furnaces from time immemorial. Chalk, which is brought as ballast from the south of England, is often used to mix with other limestones in the Cleveland and Durham districts. After evaporating to dryness, the chalk and other limestones selected for the purpose contain from 96 to 98 per cent. of carbonate of lime.

In the best works all the three ingredients are subjected to analysis, to ascertain whether they contain any objectionable element, and to facilitate calculations as to the best proportions in which each should be used, so as to produce, without any waste of materials, those chemical reactions which are necessary to free the metallic iron. The heat of the furnace drives off the carbonic acid from the lime, which then combines with the silica and other earthy ingredients contained in the ore, forming a liquid slag, while the metal itself, being of greater specific gravity, finds its way down to the bottom of the furnace. The workman is principally guided by the appearance of the slag which issues from the cinder notch, as to whether the furnace is working satisfactorily; the colour, vitrification, and transparency of the slag when cooled being some indication of the character of the iron which is being produced. So slight a change of circumstances will affect the quality of the metal, that pigs yielded by the same tapping will prove to be of two, and sometimes even of three, different qualities.

It is impossible to ascertain the temperature to which the interior of a blast-furnace is raised, but as the melting-point of ordinary pig-iron is somewhere about 2500° Fahrenheit, it must at least approach very nearly to that figure. The heat of the gases which pass off by the chimney have been roughly estimated at about 1700° Fahr. immediately above the top of the charge; and it is evident that the greatest heat must be in the lower part of the furnace, because the upper portion is being constantly cooled by the addition of fresh material. Notwithstanding the intense heat, a well-constructed blast-furnace will remain in good workable condition for several years. Some parts, however, are apt to get out of order; and the twyers, in particular, should be well attended to, as a derangement of them may readily lead to serious consequences. Cases of explosion have been known, when all the molten metal has been blown out of the hearth because the nozzles of the twyers had become leaky, and the water supplied to keep them cool found its way into the furnace itself. Accidents similar in character have also arisen from the workman omitting to tap the furnace at the proper time, and so allowing the metal to accumulate above the level of the twyers.

Four qualities of pig-iron have been spoken of; they are distinguished commercially by consecutive numbers, but are often spoken of as *dark grey*, *bright grey*, *mottled*, and *white*. They are also separated by some into two classes, *foundry* and *forge* pigs; the founders again subdividing the former according to a classification of their own. Nos. 1, 2, and 3 are foundry pigs, the white being quite unsuitable for this purpose. As a rule the lower numbers are the most valuable, white iron being indicative rather of some derangement in the working of the furnace. No. 1 generally comes off first when a furnace in good working order is tapped, and then No. 2, and sometimes even No. 3. It contains more carbon than the lower numbers, which is advantageous in some of the subsequent processes for converting it into malleable iron. No. 2, the bright grey, is the best for making castings. No. 3 is a mixture of grey and white iron; the last, No. 4, is extremely hard, and at the same time very brittle. The presence of sulphur and phosphorus tend to produce the objectionable qualities of No. 4; at other times this iron is the result of some derangement in the working of the furnace; there are, however, white irons of excellent quality which will take the earlier numbers, such as that due to the presence of manganese, which is highly prized.

Pig-iron always contains more or less carbon in combination, which may amount to as much as 5 per cent., forming a carbide of iron. This will have to be referred to more particularly in describing the puddling processes. There is generally, also,

silica present, which is objectionable on two grounds: first, that of weakening the strength of the iron; second, of causing waste of material and additional labour in puddling. Iron made by cold blast is comparatively free from this ingredient, the heat of the furnace being less intense than when the hot blast is used. Manganese has already been mentioned as being beneficial in its character; this is particularly the case when there is an excessive quantity of phosphorus, as it causes the almost entire removal of the latter during puddling. A highly manganiferous pig without phosphorus is puddled with difficulty; but when the latter is also present, the operation proceeds satisfactorily without more than the usual waste. Phosphorus alone, even when there is only 0·5 per cent. in bar-iron, renders it *cold short* or brittle. Sulphur is still more objectionable, a mere trace rendering the iron *hot short* or incapable of being worked at a red heat under the hammer. As all coal contains some little of this ingredient, and it is only partially volatilised in coking, some small proportion of it is sure to find its way into the iron, even though every precaution be taken to prevent it. If the coal used contains much pyrites, chloride of sodium is sometimes mixed with it in the coking ovens, in order to convert the sulphide of iron into a sodium salt which can be more easily got rid of; or else an additional quantity of lime is used in the blast-furnace for the purpose of taking up some of the sulphur.

Foundry pigs have already been mentioned. Before passing to the elaborate processes required to make iron malleable, it will be well to describe the use to which pig-iron, as such, is put. The articles made are commonly called "castings," and they are the work of the founder. The plan adopted in their manufacture is simply to re-melt just so much of the pig-iron as may be wanted at the time, and pour the liquid metal into the moulds prepared for it of the form required. The process, apparently very simple, requires, however, a considerable amount of nicety, and workmen of experience.

A foundry consists of a large shed, with a deep bed of sand for its floor; two or three cupola furnaces of different dimensions for melting the iron, provided with twyers and a blowing engine; travelling cranes for moving pots of the molten iron to other parts of the premises; and a large collection of models and materials for making the moulds. We will take the last of these first, so as to follow the order of the process. The moulds are made of sand, a material being required to which the iron as it cools will not adhere. Moulding sand has, however, to be specially prepared in order to make it bind properly. It should be fine and even in quality, and should consist principally of silica with the addition of a little alumina. Loam consists principally of alumina, with a little silica. It will, therefore, be readily seen that by a mixture of pure sand with loam the relative proportions of these two ingredients can be adjusted. It can be still further improved, however, by mixing with it some coke-dust ground fine. This constitutes moulding sand, and is the article of which the floor of the foundry is made. The relative proportions of these ingredients is varied somewhat, according to the nature of the articles to be made; for some purposes the moulds are made altogether of loam, which have to be carefully dried in an oven before they are used.

The making of the moulds, especially when the casting is to be either a complicated or an elegant one, requires much care and nicety, and often artistic skill. They are made in frames without top or bottom, called "flasks;" these consist of sheets of iron firmly bolted together, the lower frame having ears on its upper edge exactly corresponding with others on the lower edge of the upper frame, so that the two frames can be united with precision. The frames are placed on the floor, and some of the old sand of the floor is shovelled into one of them and rammed down firm, a little fresh sand being employed to finish off with. The model already made in wood or metal is pressed into this, and then the other frame is placed upon it and filled in with sand after the same manner. On being lifted off again, and the model taken out, we have then the impression of the two sides of the model, one in either frame, and exactly corresponding; wherever necessary the mould has to be trimmed up, and it is then dusted over with a little finely powdered charcoal. The moulder has then to make a channel through the sand for the admission of the molten iron, and also some exits for the air and gases, so that in no part of it shall the air be shut in, or the iron will not be able to penetrate, and the casting would be imperfect. These perforations are made with wires; in large castings and complicated patterns they have to be numerous, besides two or more openings for the admission of the iron, so that it may be poured in at each simultaneously.

The frames being now prepared the upper one is replaced, and the two are firmly fixed together. The iron is then poured in, and when sufficiently cool, the upper frame is removed and the casting lifted out. Adhering to the casting will be the iron which has filled the supply-channels, called "gates," which is broken off with a hammer; and when quite cold the edges, false seams, and other roughnesses are trimmed up with chisels or files. The metal having slightly contracted, the casting is generally removed without much injury to the mould, the latter being made somewhat larger than the ironwork is intended to be, so that when it has cooled down it shall be of the exact dimensions required; for this purpose the scale of the founder has to be increased by an eighth of an inch in a foot. There are many articles of very large consumption made of cast iron, such as water-pipes, wheels for machinery, some sorts of nails, railway chairs, etc., in making the moulds for which various mechanical appliances have been contrived for reducing, and almost superseding, the manual labour; these appliances not only ensure great uniformity in size and form, but effect at the same time a considerable saving of expense.

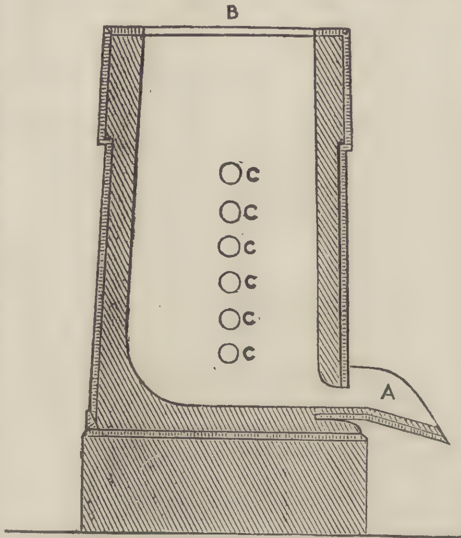


Fig. 6.

The iron is usually melted in a small cupola furnace of the form shown in Fig. 6. It is made of iron plates, lined with sand mixed with a little clay. While the melting is going forward, the spout A is stopped up with some moist clay; the charge is thrown in at the top, B; and the twyers for supplying the blast, which is generally driven by a fan, are inserted in whichever of the openings C, C, C may be desired, the others being closed up with iron plates. As the quantity of iron to be melted varies with the size of the casting to be made, the twyers are movable, as the nozzles must be placed just above the level of the molten iron. The furnace is lighted with some pieces of wood, and then filled up to the throat with coke, the spout being left open during the warming. The latter is then closed, the blast is turned on, and some pig-iron broken in small pieces, together with bits of waste metal from previous castings, are thrown in on the top of the burning coke; as the charge sinks down more coke and iron are added until the required weight of metal is reached. When the furnace is tapped the metal is received into an iron pot with a lip, which is carried either by hand or by a travelling crane to the mould, from which the iron is poured in. The floor of the foundry generally contains some large pits, in which the moulds for large castings are sunk, so as to avoid the inconvenience of having to pour in the metal at a considerable elevation.

During the melting there is some little loss of iron, as the metal will combine with any earthy matter that the fuel may contain, forming a slag which floats on the surface; pig-iron which contains silica will, however, be improved in quality by the process, of course at the expense of quantity, the silica being then converted into a silicate of iron, which will also separate itself from the metal.

THE STEAM-ENGINE.—XI.

By J. M. Wigner, B.A.

AGRICULTURAL ENGINES, PORTABLE AND FIXED—TRACTION-ENGINES—STEAM-ROLLERS—PUMPING ENGINES—STEAM-HAMMER—STEAM FIRE-ENGINES.

Thus far we have inquired into the general principles on which the steam-engine is based, and also explained the construction and action of the more common forms of stationary engines, and of those employed in propelling steam-ships. In the present paper we propose to explain the construction of those which are commonly employed for agricultural or other special purposes; and in our next and concluding paper we shall treat of the locomotive and its construction.

The steam-engine has of late been very largely employed in many agricultural operations, as, for instance, in driving threshing machines, chaff-cutters, and various other machines that are in almost constant use on the farm. Besides this, the system of ploughing and cultivating the land by means of steam power has been rapidly spreading, especially on large estates. The result of all this has been that many makers have directed their special attention to the manufacture of engines for these purposes. The main requirements in an engine of this kind are simplicity of construction, so that it may be worked with safety by the more intelligent class of farm labourers, and may not easily get out of repair; it should also be compact in form, and either portable, or so made as easily to be fixed, and, if required, to be moved again.

These engines may be divided into two main classes: those which are mounted upon wheels so as to be easily drawn about from place to place, and those which are fixed; these latter being frequently known as "independent" engines. Different makers vary considerably in details, but in their main features most of these engines closely resemble one another. They generally consist of a boiler with internal fire-box and horizontal tubes similar to those employed in locomotives. The chimney is made rather long, so as to create a good draught; but, as this would render it rather inconvenient in moving, it is jointed, so that when travelling it lies above the boiler on a special support provided for it. The cylinder is usually horizontal, and is firmly bolted to the upper part of the boiler, which is thus made to serve as a support to which all the various parts of the engine are secured. Some makers, instead of this, place a large saddle frame across the boiler, to which they fix the various fittings, and this plan seems to be gaining favour.

The connecting-rod is fixed to the piston-rod very much in the same way as in the horizontal engine already described, and thus turns the crank of a shaft which is placed across the top of the boiler a little way behind the chimney. This shaft is often so made that the fly-wheel may be fixed on either end, and the machinery is driven by a strap passing round this, or else round a special driving pulley suitably placed on the shaft.

The engine is usually fed from a large tub or other vessel placed by its side, into which a flexible suction hose is made to dip. The feed-pump is fixed to the side of the boiler, and is worked by means of an eccentric on the driving shaft. The boiler itself is well covered with felt and wood lagging, for the double purpose of economising the heat as much as possible, and also of avoiding risk of burns by coming into contact with it.

As will be seen, all the various parts of the engine are very securely bolted to the boiler or frame, and thus there is little fear of the joints working loose by the jarring and shaking incurred in moving it from place to place. The wheels are usually made with iron spokes, and a broad flange, to guard against their sinking too deep into the soft ground, over which they often have to travel. When the engine is drawn into place the shafts are removed, and wedge-shaped blocks placed under the wheels to keep the engine from shifting its position through the oscillation.

Independent engines are made very similar to this, with the exception of the wheels. The loose ash-tray under the fire-box is, of course, inadmissible, as the engine has to rest on this as a support; the fire-box, therefore, is made a little deeper, so that there may be room for the ashes under the furnace-bars. A firm pillar or iron pedestal is placed under the funnel end, and thus the engine may be placed upon two stone slabs or similar bearings without any masonry being required to fix it in position. Sometimes the support at the fore-end is so arranged as to serve as a hot-water tank, from which the boiler is fed, but this is not often the case.

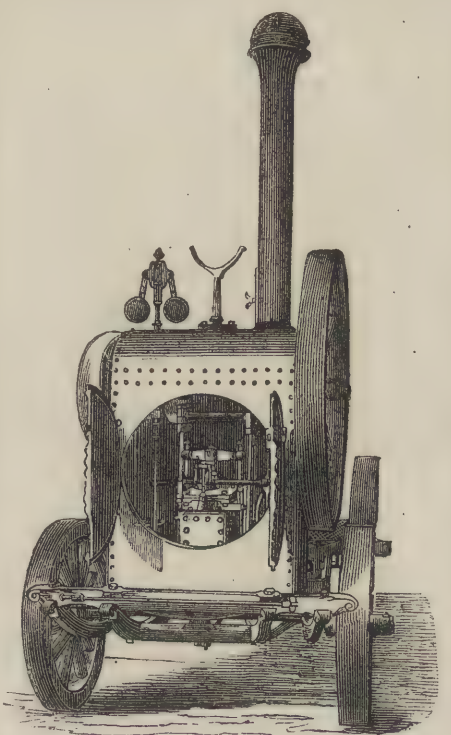


Fig. 44.

Some makers place the cylinder and the pipes leading to and from it inside the boiler or steam-chamber over the fire-box. In this way they are entirely protected, and during frosty or snowy weather there is a great benefit in this plan, as priming and condensation of the steam are thereby avoided, while at the same time there is a considerable saving in fuel. The machinery is likewise better protected from accidental injury and from rust.

In the engines made by Messrs. Tuxford, one of which is represented in Fig. 44, the funnel is placed at the same end of the engine as the furnace, and all the mechanism is contained in an iron case at the other end of the boiler, so as to be entirely under cover. In these engines the cylinders are vertical instead of horizontal, as in most other agricultural engines, and doors are provided in the end of the case, so that the machinery may easily be got at to oil or clean it when necessary. This form of engine has met with much approval; and as they usually have to work in the open air, the protection thus afforded to the machinery causes it to last much longer than it otherwise would. The gauge-cocks, safety-valve, and other fittings are the same here as in the engines already described. The chimney is provided with a spark-trap to prevent the escape of red-hot cinders or sparks; and as these engines are often used to drive threshing machines in stack-yards or similar places, this protection is very necessary.

An engine of this description is sometimes used for steam ploughing and cultivation. When this is the case, it is made to impart motion to a large drum, so constructed as to turn at pleasure in either direction. A wire rope is then made to pass along each side of the field, suitable rollers and pulleys being provided to diminish its friction as far as possible. These pulleys are fixed to anchors, which are moved from time to time as the plough travels from side to side of the field. Several ploughshares are usually fixed side by side on one frame, so that some six or seven furrows are ploughed at the same time; and a second set of shares is also fixed in the frame, which act when it travels back again to the side of the field from which it started. In this way the work is very rapidly accomplished. A rope is fixed to each end of this compound plough, and by this it is thus alternately drawn from side to side of the field, the anchors and pulleys being successively moved nearer and nearer the side on which the engine is placed. Another plan is to fix the drum to the engine, and place this at one side of the field, and a pulley with its anchor at the other side; both engine and pulley are then gradually moved along from one end of the field to the other, the plough moving backwards and forwards between them till

the whole is completed. A considerable drawback to this mode of cultivation is the expense of the rope, which is found to wear out very rapidly. Traction-engines have accordingly been tried, which travel across or round the field, drawing the various implements after them. These have not, however, answered so well as to come into very general use; the great difficulty at first arose from the engine-wheels sinking deeply into the ploughed land, but this has been overcome in a very remarkable manner. It is found that if the tire of the driving-wheel be covered with a thick layer of india-rubber, it accommodates itself to the surface over which it passes, and in this way acquires such a large bearing surface that the wheel scarcely sinks at all. At first we should imagine that tires of this sort would very rapidly wear out and become cut to pieces by the stones on the roads over which they pass; practice has, however, shown that this is not the case at all, and that they last a considerable time. In fact, the introduction of these india-rubber tires has been the greatest step yet taken towards the general employment of traction-engines for many purposes for which teams of horses are now used. "Road steamers," as they are called, fitted with these tires, have, within the last few years, been submitted to almost every test that could be devised, and have been found to work in a highly satisfactory manner, and many more are now being made both for home and foreign use.

Many traction-engines were formerly so constructed that they laid an endless railway for themselves, along which the wheels travelled. A series of wide bearing-plates were connected at the ends, and fixed to the driving-wheels in such a way that they were successively laid down for the wheels to pass over, and taken up again immediately afterwards, the whole arrangement being self-acting.

Most traction-engines are made with three wheels, the front one being made to turn in a pivot: this wheel can then be turned by means of the steering gear, and thus the course of the engine can be altered at pleasure. The various details have all been so well carried out in many road steamers now made, that they can be turned in a very narrow space and guided with the utmost precision. They have lately been employed for military purposes, such as drawing heavy guns and placing them in position, and for this too they have been found to answer well.

Occasionally engines are so constructed as to serve either as traction-engines or ordinary portable ones, and these are called combined engines. In this case there is in some convenient place a large driving-pulley round which a strap can be passed to drive any required machinery, and also an arrangement by which the driving-wheels may be thrown in or out of gear at pleasure. This may be accomplished by means of a pinion which is made to slide along a feathered axle, and thus can be made to engage in teeth fixed to the inner edge of the driving-wheels. The motion is, however, often imparted to the driving-wheels by means of an endless driving chain, which possesses this advantage, that the wheels may be fitted with springs, and thus will accommodate themselves to the irregularities of the road, and render the motion much more uniform. In this country there are many restrictions as to the use of traction-engines along public roads, especially in the neighbourhood of large towns; but now that they can be made so much more manageable and compact, these restrictions will not improbably be modified, and then we shall find their use greatly extended. In many engines of this class either driving-wheel may at pleasure be thrown out of gear, and by this means sharp corners may be turned with much greater ease.

Steam-rollers have of late years been somewhat extensively introduced into large towns for the sake of levelling roads that have been newly macadamised, and they ought to be much more generally adopted, as great inconvenience is caused by compelling this levelling work to be effected by the ordinary traffic. The steam-rollers employed are essentially heavy traction-engines with very broad driving-wheels, and so constructed as to travel at a small speed. The boiler is usually a vertical tubular one, and the surfaces of the wheels are covered with broad wearing-plates which can be renewed at pleasure. Reversing gear is provided, the action of which will be fully explained when treating of the locomotive, and thus the engine can be driven either backwards or forwards at pleasure. A wide steering-wheel is so placed in front that it rolls the space included between the two driving-wheels. By driving this over the newly-laid stones a few times the road is rendered thoroughly firm and even in a very short time, and lasts much longer; nearly all the wear of the stones against one another is likewise avoided. The roller is usually weighted with ballast, so as to bring its weight up to about twenty-five tons.

Another very important class of engines consists of those especially designed for pumping purposes. In many factories, breweries, etc., the water has often to be raised from a deep well, or forced into an elevated cistern; and for these and many similar purposes, pumps driven by steam-power are commonly employed. Besides this, in most large towns a supply of water is now provided and delivered by means of pipes to the various houses usually at a pressure sufficient to raise it to cisterns placed in the upper storeys. For this purpose very large pumping engines have to be erected, as the water has often to be conveyed from a considerable distance or raised from a deep boring. Two totally different kinds of pump have come into common use: in one, the water is raised by means of a plunger which moves up and down in a cylinder provided with suitable inlets and outlets; in the other variety, known as centrifugal pumps, a wheel fitted with curved spokes is made to revolve very rapidly inside a chamber which it just fits, and by this means a constant stream of water is maintained. These latter may be driven by any ordinary engine, but the former are usually constructed so as to be a part of the engine itself. In many large towns a beam-engine is employed, and the pump-rod is fixed on the same end of the beam as the connecting-rod, usually at a point about half-way between the centre and the end. In other cases the connecting-rod and fly-wheel are dispensed with, the piston being jointed to one end of the beam and the pump-rod to the other.

Another plan is to invert the cylinders, and thus let the piston-rod be connected directly to the plunger without the intervention of any beam or other mechanism; this form of engine is decidedly the most simple, and hence has been employed in several large water-works. The pumps are now very frequently made double-acting, so that the water is raised while the water-piston is moving up as well as when moving down, and by this means a larger amount of water is raised, and the action is rendered much more uniform. A large air-chamber is, however, nearly always connected with the main pipe just after it leaves the pump. As each stroke is made the air in the upper part of this is to a certain extent compressed, and thus prevents the sudden jar or shock which would otherwise be given to the water. The reaction of the air between the strokes of the piston keeps the column of water in the pipes in constant motion, and thus a steady uniform flow is produced; in this way the strain is much diminished, and the pump rendered more effective.

In pumping-engines that are fitted with a beam, if the strain is greater while the plunger is moving in one direction than it is during the return stroke, a counterpoise is usually affixed to the upper end of the plunger, of such a weight as to balance this discrepancy, and thus cause the work of the engine to be uniform. The power required in some of these engines may be easily seen when we remember that the average supply of water that has to be provided for a town is from twenty to thirty gallons per day for each individual inhabitant.

For use in factories and other places where a large amount of water has to be employed, pumps of a much simpler construction are often employed. In many of these the cylinder and the barrel of the pump are firmly secured to a solid bed, so as to be in one straight line; the piston is then fastened to one end of the piston-rod and the pump to the other, both engine and pump being made double-acting. In this way great simplicity is attained, there are but few moving and wearing parts, and the whole occupies but little space. Small pumps of this description, known as donkey feed-pumps, are very frequently used for feeding boilers, for which purpose they answer very well. When the feed-pump is driven from the large engine, this has often to be started or kept running slowly, only for the purpose of maintaining a sufficient supply of water in the boiler. This causes a great waste of power, and hence an independent feed-pump driven by a cylinder of its own is generally used for this purpose.

The steam-hammer is another very important adaptation of the engine, and is now employed in nearly all large metal-works and foundries. Its construction has, however, been already fully explained in the papers on "Applied Mechanics" (Vol. I., p. 410), and a figure of it has been given there, so that we need not further explain it, but refer our readers to that description.

Steam cranes and travellers are now very commonly employed in all extensive building operations, but they call for little special notice here. The boiler in them is usually vertical, and the piston makes short and rapid strokes. In the crane great care is taken to have the different parts well balanced on the pivot about which the whole rotates, and the various handles for starting and reversing the engine are so arranged as to be well under control and easy of access.

Blowing engines are frequently constructed for use in mines so as to secure a continual supply of fresh air to the various workings, and also in many foundries to urge the combustion in the blast-furnaces, and thus produce sufficient heat to melt the iron. In some of these the current of air is produced by large blowing cylinders worked by the beam; in many other cases a large fan is set in revolution by the engine, and this produces the blast.

The only other special engine we can at present refer to is the steam fire-engine. This has been introduced somewhat recently, but is of the utmost importance, especially in our large and crowded towns, where a fire when it once breaks out spreads with such amazing rapidity. In an ordinary engine a considerable amount of time is occupied in heating the water in the boiler, and getting up sufficient pressure of steam to work the engine. This, however, would never answer with a fire-engine, as almost everything depends upon having it at work as soon as possible after the fire has broken out, and before it has had time to make much way. The engine must also be extremely portable. These objects have now been attained by several makers, and various public competitions and prizes have stimulated them all to do their best.

The boilers, as we have already explained, are made to contain a very small quantity of water, and this is distributed between various tubes in such a way that it is everywhere in very thin layers, and the arrangements are such that the steam can easily rise from the internal surfaces. The tubes in these boilers are short, and packed extremely close together; this, of course, renders them very liable to become furred, but they seldom require to be worked long at a time, and they are so arranged as to be easily exposed for the sake of cleaning when necessary. The cylinder is short, being usually about seven or eight inches long, and six or seven inches in diameter. The piston moves very rapidly, making about 150 or 160 strokes per minute, and the pump is fixed to the other end of the piston-rod. The pump is double-acting, and discharges the water into a large air-chamber, from which it passes to the delivery-pipe. Some makers give a longer stroke to the piston, but in the majority of cases the short stroke is preferred. These engines have frequently been got to work within twenty minutes or less of the time that the fire was lighted; so that if the fire be lighted as soon as the alarm is given, steam is frequently got up on the road, and the engine is then ready to work by the time it reaches the scene of the fire.

OBJECT DRAWING.—VI.

SHADING.

In order that the drawing of an object may resemble the original, it is necessary that not only the shape, but that the ever-varying appearances caused by the rays of light falling upon it, should be imitated in our representation.

It is not in this place intended to enter into the subject of the *projection* of shadows, which will be fully treated of in another part of this work; but as a simple broad shade assists in "bringing out" a sketch of a solid form, a few hints are given to guide the student in shading from models.

It cannot, however, be too strongly urged that no attempt at shading should be made until the outline has been examined in every way to test its correctness; for it must be borne in mind that *no amount of shading will make up for bad drawing*, whereas a bold and clear outline may, in most cases, be made independent of any shading at all.

Only *one* light must be used when shading from a model, and this is to be placed in the manner which will best bring out the form of the object, by throwing some portion of it into the shade.

Now, if one of the rectangular solids be placed near the opposite edge of the table, the candle or lamp being situated on the side at which you are sitting, and on your left hand, then the light will be prevented falling on the *right* side and back of the model, whilst the front and left side will be fully exposed to the rays: the back and right-hand side will then be in *shade*.

But, in addition to the solidity of the object keeping the light from falling on the sides which are not opposite to it, it also hinders the light from falling on the *table*, which, near the back and right side of the model, will be darker still. This darker portion is called the *shadow*.

The distinction, then, between these two terms is, that any part of an object which does not receive the rays of light is said to be *shaded;* but when this object prevents the light falling on another surface, the part of that second object or surface which is thus obscured is said to be in *shadow*.

It may be taken as a general rule that, when the object and the surface on which it stands are of the same original colour, *shadows are darker than shades.*

Rays of light falling upon any surface are reflected from it, according as the surface is more or less polished, and the reflection will be more or less intense as the reflecting surface is of a lighter or darker colour. Any surface, therefore, which is directed towards light, not only becomes itself illumined, but casts a certain amount of light on objects opposite to it. Thus, supposing a cube is placed so that the light may fall on one side, whilst the other is in shade; if a sheet of drawing-paper is held up at a little distance from the shaded side, so that the light may strike directly on it, the rays will be reflected, and the shaded side will be visibly lighter than it was before.

On this point, Mr. Butler Williams says: "Although all surfaces that receive light do not reflect back an equal quantity, yet all do so to some extent, and to a greater or less degree according as they are placed less or more obliquely with respect to the luminous body and to other surrounding objects. Were it not for reflected light, those objects or surfaces which are not directly illumined would be so totally immersed in shade as not to be seen—their exterior figure or outline only would be visible. If an object bounded by flat surfaces be relieved by a wall or other surface, and the light be supposed to proceed from the left, we may notice three prominent varieties of tint. The lightest will be on those surfaces most nearly opposed to, or facing the light; the second will be on the side of the object from which the direct rays of the light are interrupted by the substance of the object itself; the third will be the shadow cast by that object on a part of the surface facing the light, but of which part is deprived of the direct rays of light by the interposition of the object in relief.

"Now the shade on the side of the projecting object appears lighter than the shadow adjoining, because, from the adjacent surface of the wall, a certain portion of light is reflected; and the shadow is the darkest because there is no surface near from which any strong light can be reflected to the place it covers. Shadows appear darker when cast on a surface in bright light than when cast on a surface in a fainter light or in shade; and the contrast, in the first case, between the shade and the adjoining shadow is greater than in the latter case.

"Also, in the case of a shadow falling on a flat surface, that part of the shadow which is nearest to the object which causes it is darker than the parts more distant; the shadow becomes gradually less intense the farther it recedes from the object whereby it is produced."

As the application of the principles thus laid down will be shown in subsequent objects and groups, some attention will now be given to the manner in which shading is to be accomplished.

If the drawing be small, it will be sufficient to employ the pencil to shade it. For this purpose the B will be found the best for general shading, HB for the lighter shades, and BB for the darkest shadows.

The shading should not be done by rubbing the pencil up and down, but by clear lines, which must afterwards be softened by a pencil of a slightly lighter degree; but the lines should still remain visible, though not too distinctly: and, in order to obtain the crispness and brilliancy so necessary to the beauty of a drawing, the lines should from time to time be brought out, so that they may not be lost in the filling in.

These lines are called "hatchings," and though no absolutely

universal rule can be given as to their direction, it will be found best in most cases that the *lines should follow the direction of the plane on which the shadow falls.* Thus, let us suppose it were required to shade a cube suspended against the wall, on a higher level than our eye, which is situated on the right side, whilst the light comes from a point above and on the left side of the object. It is clear that, under these circumstances, we should see the right side and bottom of the cube, both of which would be shaded, and that there would be a "cast shadow" on the wall.

The side of the cube should be shaded with vertical and the bottom with horizontal lines, whilst the shadow on the wall should again be done in vertical lines.

Curved surfaces should be shaded by lines which partake of the general curvature, and these may be crossed by others, but care must be taken that these hatchings do not cross each other at right angles, like the threads in a woven fabric; they should cross obliquely, so that the spaces between them may be lozenge or diamond shaped. None of the hatchings should be visible when the drawing is viewed from a short distance, but should form a uniform clear tint over the shaded surface.

The largest and darkest shadow should be laid on first, for if the opposite plan were adopted the learner would have difficulty in so graduating his tints that the darkest portions of the work should not become *too* dark and heavy. Still, it is to be understood that the shadows and shades are not any of them at first to be made as dark as they are intended subsequently to be, for the constant retouching which the work necessarily receives would thus make the whole too dark; whereas, by getting the shadows generally spread over the whole work, and then working on each in turn, the relation of one to the other is observed, and no one part looks faded whilst others may look fresh. It is, of course, necessary to avoid smearing the work, but this is easy with a certain amount of care.

The outline, too, will require touching up as the drawing proceeds, but it must be particularly observed that in reality there is *not a line round objects*, and that therefore the boundary line which is necessary in a drawing must not be hard and darker than other parts, which causes the drawing to appear as if it were intended to represent an object bound with a band of iron; still, the form must be clear and defined, and care must be taken that in the process of shading the outline may not become ragged.

Drawings of objects when of a large size should be executed in chalks. Those most generally used are "French Conté crayons," Nos. 1, 2, and 3, and white chalk—also sold in sticks. These are held in chalk-holders, called porte-crayons. In lieu of these, the crayon may be rolled spirally in a strip of drawing-paper, which has the great advantage of lightness; and, for economy's sake, the small pieces of chalk may be fixed in a quill.

To point these chalks a certain amount of practice is required. Having placed the larger end in the holder, scrape the other until it approaches a pointed form; then, turning it in the reverse way to that in which a pencil is held, holding it between the thumb and middle finger of the left hand, and supporting the end on the forefinger, cut *from* the point towards the body, gradually turning the chalk round between the fingers: by this means, with a sharp, broad knife, and a little care, a fine point may soon be obtained. For model drawing, *very* fine points are not generally required; therefore, when the point has once been made, it may be kept sharp enough for some time by a small file or piece of sandpaper, a strip of which may be glued on a piece of wood, like a small razor-strop. The three numbers on the chalks represent different degrees—No. 1 being the hardest.

The outline is, in the first instance, to be drawn with sketching-charcoal. This should be properly pointed, and the sketch should be lightly made. If this be done, any parts which may be deemed incorrect can be dusted off with a cloth, clean handkerchief, or a piece of chamois leather. This must not, however, be done too often, as the surface of the paper would thus become roughened, and the grain or "tooth" destroyed, and this would seriously interfere with the manipulation of the chalk. In addition to this, the habit of constantly rubbing out encourages want of care in the sketching; and therefore do not labour under the delusion that your first outline need necessarily be "only a rough sketch," but aim at correctness from the beginning.

When the outline in charcoal is satisfactory, it is to be dusted out, so as to leave merely a slight trace—just enough to guide the eye and hand. The lines are then to be repeated with crayon No. 1.

As a rule, erasure of the chalk-lines ought not to be required, since all the corrections should have been made in the charcoal sketch. If, however, alteration be indispensable, the lines may be rubbed out with stale bread, either in its usual condition, or pinched between the fingers until it is kneaded into a paste. It must, however, be understood that the use of bread always more or less unfits the paper to receive the chalk, and thus causes the shading to become spotty; and, further, the frequent use of bread makes the paper become greasy. Vulcanised india-rubber will, in some degree, remove this, but, again, the surface of the paper will suffer, so that the old adage, "Prevention is better than cure," must be borne in mind, especially so since the cure is not an efficient one; and thus again the absolute necessity for care is impressed on the student.

The paper used when the model-drawing is to be executed in pencil should be a good, firm, white cartridge, or any other which is not hot-pressed. If the paper be too smooth, the pencil glides over it, and a level tint will not be obtained without much difficulty, whilst if it is too rough the drawing will be coarse and unsatisfactory.

Tinted crayon paper is used for chalk-drawing; it may be had at various prices; but a cheap kind is now sold for use in drawing-classes and schools of art, which will be found quite good enough for general purposes. The paper generally used is of a pale grey or dull slate-colour, or drab. The colour ought not to be too positive, but should serve as a middle tint between the white chalk and the palest tints in the shading.

If the drawing be executed on white paper, it will require a background, and thus much time is absorbed, to a certain extent, unprofitably; in fact, by far more work is required on white paper, for all the middle tints have to be worked in with the chalk, which is not the case with tinted paper, as already explained.

The general ground for the shading may be laid on either with a piece of soft wash-leather, or a leather or paper "stump."

The "stump" is an implement made of chamois leather or soft paper, closely rolled until it is about the thickness of your little finger; it is then pointed at each end.

The crayon to be used for stumping is No. 2, or, for very dark shadows, No. 3. It is to be very finely scraped, or it may be rubbed on sandpaper, or filed, so as to obtain an impalpable powder. A little of this powder is then placed on a piece of waste paper, and the point of the stump is dipped into and turned round in it, so that it may be charged with the chalk.

Before, however, you touch the drawing with the stump, it must be rubbed on another piece of paper, so that the chalk may be evenly distributed over it, and that there may not be too much upon it. The quantity required must, of course, depend on the depth of shade to be executed.

The stump is then to be passed *lightly* over the surface to be shaded. If the space be narrow, the point must be used; if wide, the stump should be held almost horizontally, so that the side of the implement may be used; and for spreading the chalk over larger surfaces, the piece of wash-leather may be used for the same purpose as the stump.

The touch must be light and free, so as to spread an even tint over the paper. If you rub hard, the shade will become dark and streaky, and, further, you will injure the surface of the paper.

One end of the stump is to be kept free from chalk, to be employed for smoothing and softening the work of the other. Should one part turn out spotty, the parts which are too light must be touched with the dark end of the stump, until a level appearance is obtained.

The lights are produced by means of white chalk, rubbed on with the paper-stump; but for the highest lights the white chalk is used directly to the drawing. You will find the white chalk by far more difficult to cut than the black, and the points break off very often. Both these difficulties may, however, be lessened by cutting the point flat like a chisel, and then drawing the lines with the sharp edge.

The shades and shadows being thus laid broadly in, the hatching is to be proceeded with according to the directions given in the previous remarks.

FARMING AND FARMING ECONOMY.—IV.

By Professor WRIGHTSON, Royal Agricultural College, Cirencester.

ROTATION OF CROPS.

A ROTATION or orderly succession of crops has been adopted by all good farmers, and is to some extent enforced in agreements between landlords and tenants: the origin, uses, and modifications, therefore, of such "courses of cropping" becomes a fundamental agricultural study. When a nation becomes fixed in its habits, and the bounds of individual property become definite, the cultivator of the ground can no longer leave his exhausted field in search of untilled virgin soil. Such unoccupied soil no longer exists, population having increased and occupied it all. In such an economic condition, a rotation of crops soon declares itself to be absolutely essential. It is a matter of observation, at any time capable of proof, that a newly broken-up field will grow heavy crops of corn for a longer or a shorter period; that while the earlier crops are characterised by an almost undue luxuriance, successive harvests tame and reduce the land, and finally, if continued, impoverish it to such an extent as to render cultivation unprofitable. So soon as this takes place, cultivation will in all probability cease, and the land thus left will clothe itself with natural herbage, and "lay itself down" to pasture. So it may continue, until some change in the relative value of grass and corn-growing land, increase of population, or other cause, induces its owner to once more break it up. The once exhausted field will then appear to have renewed its strength, and again will be crowned with abundant harvests. Such is the most primitive and the most simple conception of a rotation of crops. It has been acted upon in this country in years gone by, and still obtains in countries where agriculture is backward.

Such a system, alike slovenly and injurious, has happily long ceased to exist here. The fallow, or period of rest, has been converted into an opportunity for clearing away weeds, and bringing the soil into a fine state of tilth. The Israelites were ordered to fallow their land every seven years; the Romans understood the working of fallows well, and introduced their system into this country. No longer allowed to lie peacefully under grass, the land was subjected to a rigorous course of cultivation and aëration, and it was thoroughly cleared and prepared for the reception of a corn-crop. The interval between these fallowing periods was usually three years—the basis of the three year's "shift," at one time the common rotation over almost the whole of England. Later in the history of agriculture, we find the interval increased according to the quality of the soil; some lands being able to produce three, and others four or even more crops before the fallow need again be resorted to. The benefit of a naked or bare fallow is by no means easily explained. By analogy, it was formerly elucidated by supposing that the land was by this means *rested.* The idea of land requiring "rest" is, however, only a poetical fiction. To be tired involves, of necessity, a nervous system, or, at least, some kind of vitality, whereas the soil is essentially unorganised and passive. While we recognise the necessity of a fallowing period, we must, then, abandon the notion of land requiring rest. It is a mere question of food-supply. Let the reader bear in mind the origin of all soils—namely, the disintegration of rocks—and let him also bear in mind that such disintegration is not yet complete in any soil; that the very presence of undigested and unchanged rocky fragments of the original rock is always to be found in soils, and he will have a key to the mystery of the benefits of fallowing.

The necessary constituents of plants contained by all soils exist, then, in two forms—one available, and the other not yet available. In the one form, atmospheric and other agencies have effected their reduction, solution, or freedom, and have rendered them capable of absorption by plants. In the other form, they exist as fragments of felspar, of quartz, of phosphatic nodules, indigestible and insoluble, and yet containing what at some future time will be food for plants. Let successive winters exert their influence on this last as yet unavailable inorganic matter, and it, too, will be weathered into something useful to growing vegetation—nay, the very action of growing vegetables assists in breaking it down, and thus ministers to the fertility of the soil. Now, by working a bare fallow with ploughs, harrows, and rollers, new surfaces are exposed to the air, and disintegration is accelerated; hence the advantage of summer fallowing, even without the aid of manure. To this may be added a certain small supply of nitrogen, obtained from the air during the period of fallow, through the agency of rain, and which will have a beneficial influence on the succeeding crop. Such must serve as a very brief explanation of the benefits of fallowing land; and when dressings of farm-yard manure and lime are added, we cease to wonder why a fallow should restore wasted fertility.

Rotations of crops such as are now in use have only been possible since the introduction of forage and root-crops, and at the present day they consist in judicious alternations of these crops. It is not our purpose to enter into the chemistry of rotations; such a course would involve a much more extended treatment of the subject than is at present possible. We must, then, take at least three propositions for granted: first, that the repeated growth and removal of crops from the land does exhaust it; secondly, that each species of plant, having special requirements, will, if continuously grown upon the same land, take from the soil certain constituents, leaving others not necessary for its welfare; and thirdly, that soil which may be in a certain state of exhaustion with reference to one plant, may yet be in a condition to feed another, and this for two reasons:—First, because such other plant may require a different degree or kind of nourishment from the soil, or may be capable of using more of the nitrogen contained in the air; secondly, because it may have a larger root-surface, and thus be enabled to feed where its less favoured predecessor failed; or it may occupy the ground for a longer period, and thus be able to abstract sufficient nutriment for its development. As an illustration of this last, take the case of wheat and barley—the first requiring ordinarily six months', while the second only needs four months' possession of the soil. From these considerations it is clear that a greater produce may be derived from land by an interchange of crops than by growing one species continuously. But this is not all. Farming economy usually requires the maintenance of live stock—the production of animal food as well as of grain. This necessarily gives rise to the growth of forage-crops and root-crops, for the purpose of providing both summer and winter keep. Such crops are consumed upon the land, or at the farm-buildings, and, with straw and the remains of imported foods consumed by animals, form the "manure-heap." Such crops, then, are returned to the soil; while wheat, barley, and other corn-crops are sold off the farm. They also, being for the most part broad-leaved, take nitrogen and carbon from the atmosphere, which eventually, as manure, find their way into the soil. Thus there is a difference between green-crops and forage or root-crops; the one acting as exhausters, and the latter as renewers of fertility to the soil. Judicious interchange of these two classes of plants gives us the many forms of rotations of crops now in use. Let it not, however, be imagined that forage and root-crops essentially differ from other crops in their nature, but only in their uses. Removed from the land, they would in many cases be as exhausting in their effects, and even more so than grain-crops; but consumed upon the land, they are the means of keeping up and adding to its fertility.

It will be well also to note some additional reasons why our root-crops are well calculated to take the place of the old-fashioned bare fallow. The objects of the bare fallow are twofold: it is a means both of cleaning and of renewing the fertility of the soil. Root-crops, since they are sown comparatively late in the spring, and even into summer, allow of the land being cleared previous to their being sown; and the adoption of wide drilling enables cultivation to be pursued, both by horse and hand hoes, throughout summer, and even into autumn. Again, such crops cannot be successfully cultivated without liberal applications of manure; and they are finally either consumed on the land or converted into land-manure. Hence the root-crops can be cultivated in harmony with the objects of bare fallowing, and with the following advantages over the older system:—More capital can be profitably occupied in farming; light lands are better able to support the succeeding corn-crop; more labour is employed; winter feeding of stock, and fresh meat throughout the year become possible; and the agricultural value of the land is increased.

Rotations of crops are constructed with a view to peculiarities of soil, climate, and markets, and their modification is almost endless. In giving a few examples of rotations, we

shall select them with a view to illustrating those general principles which must be kept in view in framing them. Heavy soils and light soils, peaty and calcareous soils—each are specially adapted for certain crops. Heavy lands have been named "wheat and bean" soils; light lands have been termed "turnip and barley" soils; and these phrases indicate the general adaptability of each. Accordingly, we find the heavy soils have been for the most part devoted to corn-growing, while the light lands have been employed in the cultivation of roots and the winter grazing of sheep. The heaviest soils are not adapted to root cultivation, but are more benefited by summer or naked fallowing.

Previous to laying before our readers a few characteristic rotations, we must explain the term "fallow," which is used to denote that section of the farm set apart for the special purpose of being cleaned and renewed in fertility. This may be treated as a bare fallow, in which case it is repeatedly ploughed and worked, and finally sown with wheat early in the autumn; or it may be prepared and planted with roots, or a forage crop, in which case it is termed a root or green crop. Every rotation commences with some form of fallow, and a fallow is invariably succeeded with a grain-crop. Usually this grain-crop is seeded down with grass-seeds, planted among the young growing corn, which continue to exist in a subjective manner until after harvest, when they occupy the ground, becoming the crop for the succeeding year. In some rotations these "seeds"—*i.e.*, mixtures of clover and grass seeds—so occupy the land for one, and in others for two years, after which they are broken up for a corn-crop, which again may or may not be followed with a second corn-crop. Sometimes beans or peas take the place of the seeds, and prepare the land for a crop of wheat.

We have already mentioned the old three-course shift as having been at one time general throughout England. The course commenced with fallow, after which was wheat, followed by beans. This course is still pursued in some backward parts of the county. It will be seen to be essentially a clay-land rotation, and one altogether inconsistent with the maintenance of live stock. It, however, affords a good instance of the manner in which a rotation may be modified. The original fallow, wheat, and beans may be converted into—

$$\left.\begin{array}{l}\text{Half fallow }(a)\\ \text{Half swedes }(b)\end{array}\right\} : \text{ wheat } : \left\{\begin{array}{l}\text{Half beans }(a);\\ \text{Half seeds }(b);\end{array}\right.$$

or, at length, into a six-course, as follows:—

Fallow: wheat: beans: swedes: wheat: seeds.

Here we have one-third of the land in fallow, one-third in wheat, and one-third in beans and seeds. It is still suitable for clay soils, but is in accordance with modern requirements. A rotation similar to this obtains in some parts of Essex. From two crops and a fallow, we pass to three crops and a fallow—a course suitable for the same class of soils, but of better quality. Thus, in South Bucks and parts of Oxon the following course is said to be in vogue:—

Fallow: wheat: beans: clover, or peas.

Again, we find rotation for clay soils in which five crops are taken between the fallowing periods. Thus, upon the good clay soils of Holderness the following course has been in use:—

Fallow: wheat: clover: wheat: oats: beans.

On the Carse of Gowrie even a more exhausting rotation has been adopted, namely:—

Fallow: wheat: barley: clover: oats: beans: wheat.

In this case it must be borne in mind that the oat-stubbles are heavily dunged for wheat.

In examining such rotations, fallow, clover, and beans must all be looked upon as good preparations for grain-crops, especially for wheat, which will do well after any of them. They are, however, all deficient as means for providing food for live stock; and we close this review of clay-land rotations by briefly describing a plan submitted to the Royal Agricultural Society some years ago by Mr. Stace, of Sussex, which will be found in the fourth volume of the Society's "Journal." This was an attempt to reconcile the maintenance of his stock with a course of cropping suitable to clay soils. The difficulty in feeding stock upon a clay soil may be thus stated. The root-crop can neither be fed off in the winter upon the land, nor carted off the land in wet autumn weather, without injury to the soil. The land is trampled with sheep in the one case, and with horses in the other. This is the great difficulty in root cultivation upon strong land, and to obviate it Mr. Stace recommends a system in which summer feeding of sheep was substituted for winter grazing. Accordingly, he proposed to grow forage crops during summer, and to feed them off the land in time to sow it with wheat. The plan proposed by Mr. Stace was as follows:—

1st year.—Winter vetches consumed on the land in May and June; followed with swedes, turnips, and rape. The root-crop and rape fed off as early as possible in autumn.
2nd year.—Wheat; seeded half with trefoil, and half with clover.
3rd year. { Trefoil, mown early, and sown with turnips to be fed.
Clover mown and fed.
4th year.—Wheat.
5th year.—Winter beans, followed with winter vetches as above.

It will be observed that this rotation has many advantages. The land is stocked with sheep during summer and autumn, when treading will not injuriously affect the land. The tillage is concentrated upon the time of year when clay lands work easiest—namely, autumn, when wheat, beans, and winter vetches all demand attention. The soil also is occupied with crops suitable to its character. On the other hand, it may be objected that there is too much work thrown on to one season of the year, and that it will be impossible to carry out such a system of cropping unless with the aid of steam. Also, that however suitable such a course may be for land in the south, it would be impossible to take turnips after vetches, or to adopt such a system of "catch-crops" in the north. These are serious objections; but we would urge, first, that with steam much may be done; and, secondly, that although the whole of a farm could not, perhaps, be managed upon this principle, yet a portion of the land might be so cropped as to ensure summer food for sheep in the manner proposed by Mr. Stace.

Perhaps no rotation is better known or has been more widely used than the Norfolk four-course. It appears in every county, and during some recent years, farms cropped upon this system have received first prizes given in connection with the Royal Agricultural Society, both in Oxon and Shropshire. The Norfolk four-course is as follows:—

Roots: barley: seeds: wheat.

It has been objected to as being too short, and because both roots and seeds occur too frequently. The rotation has been modified by allowing the seeds to remain two years, thereby changing it into a five-course; also by planting a proportion of land with beans or peas after barley. The Northumberland rotation is similar to the above, and comprises the following crops:—

Roots: barley or wheat: seeds: seeds: oats.

The East Lothian rotation furnishes us with the following succession, in which potatoes play an important part:—

Roots: barley, or wheat: seeds: oats: potatoes: wheat.

On calcareous soils, leguminous plants, such as clovers, beans, peas, and vetches, usually form a conspicuous feature; on peaty soils, rape, kohl-rabi, and oats are widely cultivated; on light soils, we find turnips and barley in perfection; and upon strong or stiff soil, wheat, beans, mangel-wurzel, cabbages, and kohl-rabi give excellent results. Thus upon each class of soils we shall find rotations framed with the view of introducing the most suitable crops.

We have, in the foregoing remarks, recognised rotations as valuable. A slavish adherence to any one of them is, however, bad; and the intelligent farmer should be able to exercise his judgment in the cropping of any particular field, instead of being trammelled by vexatious restrictions. Thus, two white straw-crops can be successfully grown in succession upon the same land, as has been proved again and again, and in some cases it is a course to be commended. Clauses which forbid such a method of cropping may be properly stigmatised as meddling; for, as has been well observed, you can neither prevent bad farming, nor command good farming, by lease-clauses. The true method of securing good management is, by a liberal policy, to encourage tenants of intelligence, capital, and position, who may then be allowed to farm to the best of their abilities, with as few restrictions as to management as is consistent with the true interests of the landlord.

WEAPONS OF WAR.—XII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

BALLISTIC INSTRUMENTS.

A BRIEF description of the instruments which have from time to time been invented to determine the velocity of projectiles is proposed to be the substance of this paper. To clear the subject a little, it will be necessary to explain some of the advantages which may arise from knowing at what rate projectiles are moving through the air. The greater velocity any projectile has (*cæteris paribus*), we get—(1) greater range; (2) flatter trajectory; (3) greater penetration and destructive effect; (4) greater accuracy of shooting; in fact, four points which are of the greatest importance in artillery or rifle practice.

The maintenance of the velocity of a projectile over a certain distance depends on the amount of resistance experienced by it from time to time in its passage through the air; the greater the resistance, the greater is the loss of velocity, and *vice versâ*; so that it becomes a problem of considerable interest to determine experimentally what the actual resistance is to differently shaped projectiles, when moving with different velocities. For instance, you might get a high velocity with a spherical ball, and yet it might be inferior for an extended range, on all the four points mentioned above, to an elongated projectile fired with a lower velocity out of the same gun, chiefly for two reasons: (1) the increased resistance it actually meets with in its passage through the air; (2) the decreased weight which renders it less able to overcome the resistance of the air. So that supposing the two projectiles were started at the same instant, the spherical projectile would go ahead for a short distance, but would soon be overtaken by the elongated projectile, and finally strike the ground at a much shorter distance from the starting-point.

Let us now proceed in the description of some of the most successful of the instruments which have been devised for measuring the velocity of projectiles.

The ballistic pendulum was the instrument which gave the most practical results before the discovery of electro-magnetism; and Dr. Hutton, Professor of Mathematics at the Royal Military Academy, Woolwich, made a series of experiments from 1775 to 1791, from which he deduced his law of the resistance of the air, which, although it fails for low velocities, yet for velocities above 1,300 feet-seconds gives a fair representation of what actually takes place for spherical shot. Considering the roughness of the instrument, it is remarkable that such good approximate results should have been obtained.

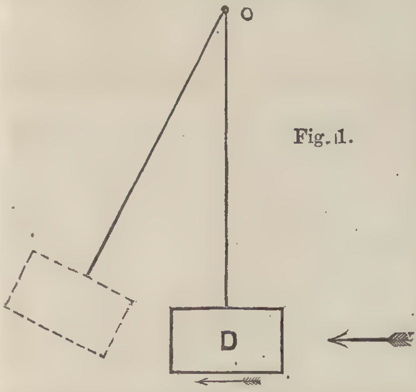


Fig. 1.

The ballistic pendulum (Fig. 1) consisted essentially of a receiver, D, commonly filled with sand, connected to the point of suspension, O, on which it could turn freely like an ordinary pendulum. The projectile was fired into this receiver, thus impressing the whole of its momentum to the pendulum, which recoiled through a certain angle varying with the velocity and weight of the projectile. This angle was carefully read off by means of a graduated arc attached to the instrument; whence, by a mathematical calculation, the velocity of the projectile at the point of impact was determined. The suppositions on which these calculations depended could never be *strictly correct*; hence the results obtained could not be regarded as anything better than an approximation to the truth. For instance, it supposes that during the penetration of the projectile into the sand the pendulum remained at rest, and also that the direction of the blow acted horizontally. There was also difficulty in striking the pendulum, so that there should be no vibration for impulse on the axis of suspension. As the distance from the gun increased, these difficulties became almost insurmountable. These defects, as well as the expense and unwieldy character of the machine, pointed to the desirability of contriving a simpler and more portable instrument to effect the same object.

Major Navez, of the Belgian service, was the first who succeeded practically in obtaining the velocity of projectiles by means of electricity. The instrument he devised was called the electro-ballistic pendulum, the pendulum being used to measure time instead of the force of the blow, as in the former instance.

This pendulum is capable of revolving about a horizontal axis through the point of suspension. A galvanic current circulates through an electro-magnet in the instrument, and through the screens, which are made of thin copper wire. When the current is circulating through the electro-magnet, the bob of the pendulum is raised up to its highest point, and kept there by magnetic attraction; and when the current is broken by the shot cutting the wire in the first screen, the electro-magnet becomes demagnetised, and the bob falls by its own weight. When the shot reaches the second screen, it cuts a wire through which another galvanic current is circulating, and consequently demagnetises a second electro-magnet which had been supporting a small weight. This weight in falling completes a third galvanic current, which sets in action a third electro-magnet, thus clamping a light index which had been travelling with the pendulum from its position of rest. The position of this index is read off on a graduated arc, and indicates the angle through which the pendulum had moved when the third galvanic stream was closed.

Another instrument called a "disjunctor" is used to break simultaneously the wires in the two screens, and the position of the index is read off as before to eliminate the errors of the falling weight, etc. etc., so that the difference between these angles represents, when converted into time, the actual interval which has elapsed during the passage of the shot from the first to the second screen. This being a certain measured distance, the actual velocity in feet-seconds is easily calculated.

Colonel Leurs introduced some modifications into this instrument, which have improved it considerably, making the observations obtained by it more reliable. He made use of two pendulums, one of which carries with it a registering needle, attached to a washer at the axis. The right-hand pendulum is provided with an arc of a circle, having the axis for its centre, upon which slides a steel strap and thumb-screw. Two springs are so arranged that when the right-hand pendulum falls the steel strap strikes the end of a lever, and releases the two springs, which at once close on the washer of the needle and fix the latter in position. The distance from the strap to the stem of the pendulum determines the position of the needle on the graduated arc, when the disjunctor is used. The difference between the length of this arc obtained with the disjunctor and the arc registered by the needle in actual trial, is the arc required. This modification of the instrument is usually called the "Navez-Leurs."

In the Navez and Navez-Leurs instruments, the time is measured by the arc passed over by a pendulum. This method of measurement is liable to *variation*, and a committee of reference appointed by the War Office has reported as follows:—"The time of describing any given arc is, of course, affected by friction; and in order to take this into account, the time of describing the same arc by a simple pendulum unaffected by friction is multiplied by a factor, the value of which is found by observing the instrumental measures which correspond to intervals of time which are known *à priori*, such as the time of a body falling freely through a given small space. It is found, however, that the *value* of this factor is *very sensibly different* for different parts of the arc of oscillation of the pendulum. Practically the factor is determined by means of falling weights with which the instrument is furnished, for a considerable arc, beginning a certain distance below the starting-point of the pendulum, then for another considerable arc beginning where the former ended, and similarly for a third; and in the conversion of an arc actually observed in the use of the instrument into time, the different values thus obtained are applied to the corresponding parts of the total arc described by the pendulum. On account of the very sensible variation of the factor, it may be doubted whether this mode of converting arc into time possesses a degree of exactness answering to the delivery of the instrumental indications. Thus, while indications nearly equal

to each other may be compared by means of this instrument with great accuracy, we do not think that quite the same confidence can be placed in its determinations of *absolute velocity*, or of *relative velocity* when the difference between them is considerable. The case is somewhat similar to that of comparing different temperatures by means of a very sensitive thermometer, which, notwithstanding very sensible variations of bore, has been calibrated on the assumption that for very considerable portions of the interval which separates the standard points, the bore may be taken as uniform."

This error has been obviated in a chronograph invented by Captain Boulengé, also of the Belgian Artillery, in which the time is measured by the space passed over by a falling weight; while the employment of the electro-magnets is the same as in the Navez-Leurs. A long cylindrical rod is suspended vertically by an electro-magnet in connection with the first screen. Another electro-magnet in connection with the second screen suspends a shorter rod, which in falling strikes a trigger which releases a knife so as to mark the zinc tubes attached to the longer rod. These several operations require some definite time, which is allowed for by using a "disjunctor" under exactly the same conditions.

When the shot strikes the first screen the longer rod commences to fall; and when it strikes the second screen the shorter rod commences to fall, and releases a knife to cut the zinc on the longer rod.

The space through which the longer rod has fallen represents (when corrected for the disjunctor reading) the time the projectile has taken to traverse the distance between the two screens; and this distance being accurately measured, the velocity of the projectile is easily calculated.

All these instruments before described are only capable of measuring one velocity of a projectile; but it is possible *roughly* to measure the resistance of the air by using two different instruments, so as to get two velocities at two different points in the path of the projectile.

We are indebted to the Rev. F. Bashforth, B.D., Professor of Mathematics to the Advanced Class of Artillery Officers at Woolwich, for the accurate experimental investigation of the law of the resistance of the air to projectiles moving at a high velocity.

His chronograph consists essentially of a cylinder mounted vertically with a horizontal fly-wheel attached to it. Two markers attached to two different electro-magnets mark a uniform spiral on the revolving cylinder. One of the electro-magnets is connected with a galvanic battery which circulates through the screens, usually ten, which are placed at equal intervals apart. The other electro-magnet is connected with a galvanic battery, which is so arranged that a pendulum clock beating seconds interrupts the galvanic current once a second, and so moves the marker out of the uniform spiral, and thus gives a scale of time. When the circuit which circulates through the screens is broken, the marker in connection with the first electro-magnet is moved out of the uniform spiral, thus giving as many marks as there are screens. These intervals are carefully measured, and compared with the time scale; whence the velocity at the middle point of each space between the screens is obtained, and the actual resistance of the air at those velocities.

The *differential* character of this instrument makes the results obtained from it worthy of a high degree of credit, "since in this way each experiment supplies means of testing the accuracy of the results, which are *wholly wanting* when only two intervals of time are measured, and that by two different instruments."* The committee further report "that they do not think that any means existed before of recording a number of successive small intervals of time with the degree of precision and trustworthiness attained by Professor Bashforth's instrument." Professor Bashforth has also introduced a "gravity chronograph" for measuring velocities rapidly and accurately on a similar principle. In this instrument only one electro-magnet is used, which is connected with one galvanic current, and the marker, instead of tracing a spiral on the revolving cylinder, makes a small hole on the paper. The time, half a second, is measured by a weight falling freely through a space of 4·02 feet. When the weight commences to fall the current is broken and a mark is made, then the projectile breaks the current when passing through the screens, usually three, thus giving three marks; and finally, when the weight reaches the bottom, the current is again broken, and a fifth mark is registered. Thus—

A (1) (2) (3) . B

. . . .

represents the records on the cylinder. A B, length of half-second; (1) to (2), time on the same scale the projectile takes to pass from first to second screen; (2) to (3), ditto from second to third screen. The second screen is not necessary for the observation of a velocity, but is only introduced as a check to see that the spaces are consistent. Knowing the distance between the first and third screens, the velocity is easily calculated by simple proportion, or can be read off by means of a slide-rule.

By the use of five screens, the resistance of the air can be more accurately determined with the gravity chronograph than by the use of two instruments, either of Boulengé or Navez-Leurs, although not with such thorough reliability as with the chronograph before described, on account of the possible slight variation in the velocity of the fly-wheel, during the half-second.

A chronoscope has also been contrived by Captain Andrew Noble, of Elswick, for measuring the velocity of projectiles in the bore of a gun. The principle is much the same as in the Bashforth chronograph, but the method of registering the breaks in the current is different. In the Noble chronoscope the mark is given by a spark on a blackened circular disc, made to revolve at a high velocity by means of toothed wheels—the mean velocity of which is measured by a stop-clock. This method of measuring time does not appear capable of so great accuracy as that adopted in the Bashforth chronograph, but it is said to give reliable results by those who have used it.

Experiments conducted with these two instruments form the basis of some very valuable knowledge in the science of gunnery, and will probably lead to still further investigations of the subject.

TECHNICAL DRAWING.—XLI.

DRAWING FOR STONEMASONS.

FREEHAND DRAWING FOR STONEMASONS.

In a previous lesson (Vol. I., page 47) we have said: "It is advisable that the student should be informed that *all* the drawing which is necessary for the artisan cannot be done with *rules and compasses*, but that some portion of the work must be done by free-hand."

These remarks apply with equal force to stonemasons. Surely, it cannot be right for a man to make up his mind that because a templet cut out of zinc, etc., is given him, his sole work in life is to place it against the end of the block of stone, scribe round it, and chip away until the block is the same shape all along—to work a plain surface to a block, to work accurate joints, or to set the stones according to the working drawings; although all such work, and very much more, is not only important, but absolutely indispensable to the mason. But the workman must remember that he is not a mere machine; that knowledge and intelligence are required in every branch; and that the more accurately the eye is educated to appreciate carved forms, the more readily will the hands execute the work. The manual skill of our stonemasons is unquestioned; the noble buildings daily rising up around us testify to this; and it is to urge on the British workman the necessity for increased mental culture and refinement in skilled labour that these lines are written. A mason may not have to design a moulding, a drawing or templet of which is furnished him by the architect or foreman of the works, but it cannot be doubted that he will execute it more readily and with greater accuracy if he understands the geometrical construction or appreciates the relation of one curve to another; and his knowledge will enable him to work with interest and intelligence, instead of by mere rule of thumb or, as it were, instinct. Besides this, the line which separates some branches of masonry from stone-carving is difficult to define—the one grows out of the other; and although every man should determine to do his best in his particular vocation, it is still his bounden duty to use every

* *Vide* Report of Committee of Reference on Chronographs, published by War Office. Page 157.

endeavour to raise himself, and this can only be done by earnest study and perseverance. To the young artisan this is particularly addressed, and he is urged to follow up the elementary course of studies here laid down; thus, as he advances in years, he will advance in knowledge, and instead of going to his work as a mere day-labourer, he will throw his spirit into his occupation, and it will become to him a labour of love.

The schools of art which, thanks to the Government Department of Science and Art, are now widely spread throughout the country, afford means of instruction of the highest character. The admirably-arranged course of studies adapted for each branch of practical art, the collections of casts, libraries, and, above all, the excellent teaching to be obtained, all offer opportunities not previously open to working men, and of which they are urged to avail themselves.

In order to economise space, Fig. 372 may be used by the learner as three separate studies, of which the easiest may be taken first. Draw the vertical line A B, and the oblique line C D on the *right* side, giving the general inclination and extent of the curve to be drawn.

Now set off between C and D the points E and F, and draw lines at right angles to C D. Make these equal to E H and F G, and trace the curve through D, G, and H to C.

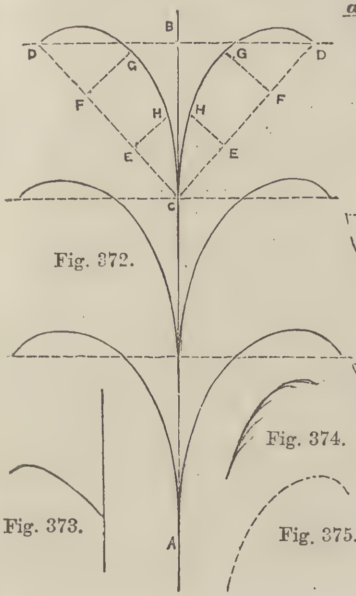


Fig. 372.

Fig. 373.

Fig. 374.

Fig. 375.

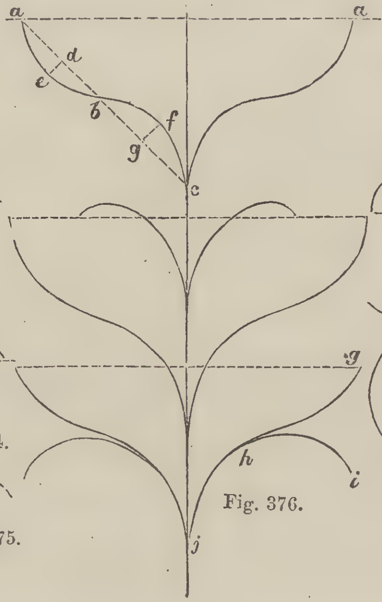


Fig. 376.

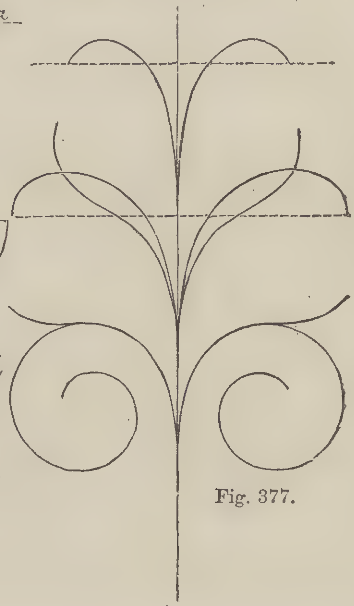


Fig. 377.

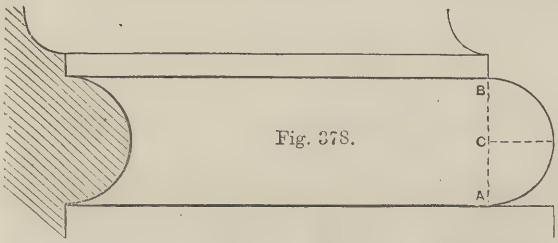


Fig. 378.

Fig. 380.

Fig. 379.

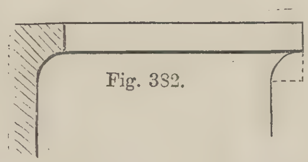


Fig. 382.

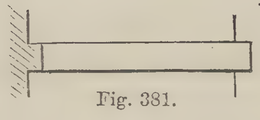


Fig. 381.

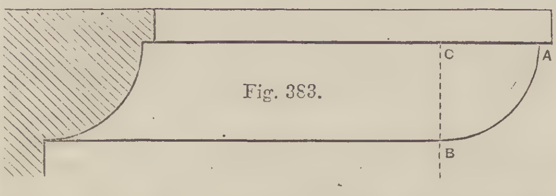


Fig. 383.

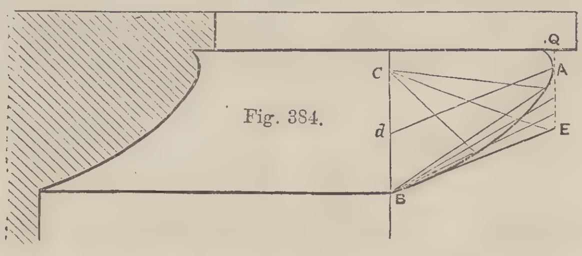


Fig. 384.

It must be pointed out that the curve must not spring suddenly or abruptly out of the perpendicular line, as shown in Fig. 373, but must merge so gradually into it that it shall become at last a portion of the straight line. This will require some little practice to accomplish, but as it is one of the most important points in ornamental drawing, attention is at once called to it.

The two lower curves on the same side may now be drawn, each a little larger than the one preceding it. The straight lines used in the first curve are, however, merely intended as leading-strings, and therefore, as soon as the smallest amount of power has been attained, they should be rejected, and the curve drawn without such extraneous aid.

Proceeding now to a further stage of the study, draw another vertical line, and draw the curves on the *left* side, which in the present study will be found rather more difficult to draw than those on the other; the hand should be placed rather higher up on the paper, and the pencil should be held rather longer than in the previous practice. It may here be well to mention that in free-hand drawing generally the pencil should be held as long, and the eye should be kept as far from the paper, as may be convenient. By these means freedom of hand and a just view of the form is obtained.

In sketching, these curves should be at first very lightly traced. They should not be made up of repeated scratches touching or crossing over each other, as in Fig. 374, but of small pieces, which in themselves form portions of the line to be drawn (Fig. 375).

Having thus practised the method of drawing simple curves inclined towards the right and left sides, the example may be copied as presented in the figure, the great object to be kept in view being that the curves must *balance* each other—that is, that the one on the right must be the exact counterpart of that on the left.

Draw the vertical line A B, and the horizontal D D crossing it; set off on this the distance to which the curves are to extend—viz., D, D—and on the perpendicular mark the point C. Now, whenever lines are to be balanced, the one on the left side should be the first drawn, for it will be clear that if the curve on the right side were sketched first, the hand would cover it whilst drawing the other, and this would add much to the difficulty of balancing the different parts. Horizontal lines, in order to regulate the heights of the curves, may be used in elementary practice; but after a while a few touches rapidly sketched across will be found sufficient, and all squaring of free-hand forms should be discarded.

Fig. 376.—The lines which form the subject of this study differ from the previous ones, in being each composed of two distinct curves.

It will be seen that the curve starting from *a* proceeds as far as *b*, and then turns in another direction. This peculiar bend requires much care, for the exact position of the point at which the change takes place materially alters the form. In order to afford some guide to the student, the line *a c* is drawn, and the change of direction in the curve takes place at the point *b* of this line.

As in the last subject, it is intended that the single curves should be practised before attempting to balance them.

Draw a vertical line, and a horizontal at its extremity; draw *a c* at the required inclination, and mark on it the point *b*.

Now divide *a b* and *b c* into equal parts, and draw the lines *d e* and *f g* at right angles to *a c*. Make *d e* and *f g* equal to the depth of the curve; then, commencing at *a*, trace the curve through *e*, *b*, *f*, to *c*.

Care must be taken that there be not a sudden bend at the juncture, but that the curves may flow gracefully and imperceptibly into each other.

Assuming, then, that the student has had some practice in drawing the separate curves as they appear on each side of the vertical line, he may then proceed to draw the complete subject, aided at first by the guide-lines, and subsequently rejecting them.

In the two lower curves the practice is advanced to a curve growing out of another. This is another important point in ornamental drawing, and has been referred to in relation to Fig. 372. It will be seen that, although the branch *i* springs from *h*, it does not project suddenly from the curve *g j*, but merges gracefully out of it; so that if the part of the curve *g h* were removed, the curve *j h i* would still be complete; and if the branch *h i* were taken away, the remaining curve, *g h j*, would not be interrupted.

Fig. 377.—In this study, the practice afforded in both the previous lessons is applied; the simple and compound curves being employed, and the branch carried round so as to form a simple scroll. The student is urged to copy the whole of the figures given in this lesson several times, as the practice they afford is of the utmost importance to him.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Mouldings.—When the face or edge of any work is wrought into long regular channels or projections, the sections of which form various curves or rounds, hollows, ogees, etc., it is said to be *moulded*, and each separate member is called a *moulding*.

Mouldings are divided into Grecian, Roman, and Gothic.

Grecian mouldings are formed of some of the curves known as conic sections, such as the ellipse or hyperbola, and sometimes even of a straight line in the form of a chamfer.

Roman mouldings have their sections composed of arcs of circles, and thus they are found the easier for elementary practice in drawing.

Fig. 378.—This is the simplest of all curved mouldings, and is called the *torus*. It is simply a semicircle described upon the vertical diameter, and is used in the bases of columns.

To draw the torus, let A B be the height of the member. Bisect A B in C, and with the radius C A describe the semicircle.

The torus, when very small, is called an *astragal* (Fig. 379), which projects; but it is termed a *bead* (Fig. 380) when it does not stand out beyond the surface. Several beadings placed together are termed *reedings*.

A *fillet* is a small flat face (Fig. 381) placed between mouldings to divide them.

A fillet is, in the bases of columns (as shown in Fig. 378), and at the top, as in Fig. 382, joined to a face or to the column itself by a small quarter-round hollow, called an *apophyge*. The word is originally Greek, and signifies "flight." English architects and builders generally term it the "scape" or "spring" of a column.

The method of drawing these is so very simple that it is not deemed necessary to do more than refer the student to the examples.

The *ovolo* (the name of which is derived from the Latin word *ovum*, "an egg") is a projecting mould, which in the Greek styles is a portion of a conic section, but which in the Roman is merely a portion of a circle—generally a quadrant—in which case it is called a "quarter-round" (Fig. 383).

To describe a Roman ovolo or quarter-round, let A be the upper extremity and B the lower. At B erect a perpendicular cutting a horizontal drawn from A in C; then, with radius C, describe the quadrant or quarter-round.

To describe a Grecian ovolo (Fig. 384), two tangents being given, as also their points of contact. Let A E and E B be the tangents; A and B the points of contact. Complete the parallelogram B *d* A E.

Produce B *d* to C, and make *d* C equal to *d* B; divide E A and A *d* each into the same number of equal parts. Through the points of division in A E draw lines to B, and from C draw lines through the points of division in A *d*. These lines intersecting those previously drawn, will give the required curve, which is a portion of an ellipse; the upper part A Q is a continuation of the same curve.

BRICK AND TILE MAKING.—III.

BY GILBERT R. REDGRAVE.

BRICKS AND TILES.

As brick-making is one of the oldest arts, so also are the appliances used therein amongst the most antiquated of any of our manufactures. Till within the last few years machinery, which was working such wonders in other branches of industry, was wholly ignored in the brick trade; and its introduction has been attended in many parts of the country with the most disgraceful and scandalous outrages and strikes. Near Manchester the bricklayers refused to use the machine-made bricks, and struck work; and the operatives in the brick-fields placed needles in the clay to maim those who had to use it. The machinery was frequently maliciously damaged, and the unburnt bricks trampled to pieces and destroyed wholesale.

Having in our two former articles treated of the preparation of terra-cotta, we now propose to glance at the processes employed in brick-making. In former treatises it has been usual to give numerous and accurate details of the mode of making bricks by the common old-fashioned method of hand moulding. We wish rather to treat of the manufacture as improved by the use of machinery and modern appliances, and as practised in the neighbourhood of most of our large towns at the present day. The two principal processes of producing machine-made bricks depend upon the state of the clay during the operation of moulding, and are known respectively as the dry or semi-dry and the plastic processes. Of these the dry or semi-dry is the more recent, and the plastic the older method. It will readily be understood that in dealing with plastic clay the material has, previous to its use, to be carefully tempered and prepared; and in the more perfect of the plastic brick-making machines we have accordingly apparatus for effecting this object. For the dry or semi-dry process all that is neces-

sary is to reduce the clay to a tolerably fine state of division, which can be cheaply and readily done in an edge-runner or vertical mill; the production of bricks from this ground clay then merely depends upon the pressure which is applied to the dust in the moulds; for, as it is well known, nearly any homogeneous substance when ground to a fine powder can be consolidated to a surprising extent if exposed to great pressure. After this brief outline of the two chief modern systems, we may proceed to examine more minutely the details of each plan of working, beginning with the dry process.

The clay, as it comes from the pit or quarry, with little or no selection, and with no preparatory exposure to the influence of the weather, is conveyed to the edge-runners or other machinery used to pulverise it. We have mentioned the edge-runner, as this form of grinding is most frequently resorted to, owing to its cheapness and simplicity. This machine, as used in the neighbourhood of Leeds, has the bottom of the pan perforated with numerous small holes, through which the ground clay drops into the hoppers placed beneath it. Sometimes these mills have openings in the side of the pan, and in this case the contents are pushed by means of scrapers on to belts, which convey the materials to the sieves and elevators. Some firms use the disintegrator for grinding the clay; and this machine, though it takes a great deal of power, is an admirable and efficient mode of grinding. It may be briefly described as a series of cages of iron bars, which are made to revolve rapidly in alternately different directions. Into the centre cage the material to be ground is gradually introduced, and as it passes through from cage to cage it comes in contact with, and is carried round and round by the rapidly-moving bars, and dashed to pieces, escaping finally on the circumference of the outer cage in a finely divided state. A six-foot disintegrator will crush 180 tons of hard clay in ten hours, at a cost of little more than 6d. per ton, which is far below the cost of any other method of grinding we know of. For a common class of brick it is not necessary that the grinding should be very fine, though a tolerably uniform size for the grains of clay is of importance, and it is usual, therefore, to screen or sift the clay powder, which can be done for about a halfpenny per ton.

There are many dry-process machines before the public, and it would be invidious in such an article as this to single out any particular maker for special reference. The general principle arrived at in all cases is the same—namely, to provide a simple and expeditious plan of filling the moulds with the powder, applying the pressure, and of relieving the mould, and finally of delivering the moulded brick. A simple and useful form of the dry press is that which has a movable plate or table, which carries one or more moulds or dies. This table closes the orifice of a large hopper containing the ground clay; but, by a traversing motion which is imparted to it, the moulds which form recesses in it are constantly carried back to the hopper to be filled, and, on moving forwards, the level surface of the table again closes the hopper. The moulds having been thus filled, and brought under the pistons of the press which carry the plates or pallets to form the top, are then subjected to heavy pressure, either by means of steam, a hydraulic ram, a cam-wheel, or a stamping action, like that of the coining press. This pressure or blow may take effect only on the top of the mould, or on the bottom, or on both surfaces combined, and need, of course, only be instantaneous; though we are inclined to think that better work is done by a slow and gradually increasing weight, like that given by a cam, than a rapid blow such as is given by a screw-press. Having received the pressure, the brick is then forced out of the mould, either upwards to the level of the table, by causing the bottom of the mould to rise, or downwards by dropping the bottom plate with the newly-formed brick upon it. We like those machines best which lift the brick to the level of the table, and then, with a sliding arm, propel it to the edge of the table, in a convenient position for removal, while the next one is being pressed. Such machines are termed "self-delivering;" and in some a series of runners, covered with flannel, convey away the newly-formed bricks. Of course, in all the machines where the brick is made under pressure, the moulds have to be very strongly made of metal, and have also to be coned or sloped slightly outwards, in order to admit of the ready removal of the brick. Another matter which has to be attended to is the oiling of tho mould. This should take place very frequently, if not after the withdrawal of every brick. The best machines are so arranged as to oil the mould each time with a brush or piston, which is in constant contact with oiled waste or wool. Machines of this kind are known as "self-lubricating."

It will readily be understood that as the clay for making pressed bricks in the way we have just described is used almost dry, they do not require to be "hacked" or stacked very long before they are ready for firing. Indeed, if the clay is used in too moist a state the water is squeezed out of it in the press, and its shape and appearance is spoiled. The consistency of the pressed bricks on leaving the mould is such that they can very readily be handled and built up in hacks to dry. We are convinced that there is no kind of kiln better adapted for drying and firing bricks than Hoffmann's; and we shall, therefore, in the first instance, describe this class of kiln. The upper surface of this kiln, on being roofed in, forms a most convenient drying floor for the bricks, and they may be wheeled up here from the presser, and stacked for a day or two so that they may become thoroughly dry.

The so-called "annular kiln" consists of a series of compartments surrounding a central chimney, and these compartments are so arranged that they can be connected together or separated from one another at pleasure by means of movable screens or partitions; and each compartment can in succession be placed in connection with, or cut off from the chimney by an arrangement of dampers. At the upper part of each compartment are numerous small orifices for the introduction of the fuel, and a door through the side wall of the kiln gives the means of filling and removing from each section the materials to be burnt. The kiln may with advantage consist of from ten to twenty compartments, each one of which would hold on an average 15,000 bricks; and the kiln, when in full work, may be filled and emptied at the rate of one compartment in every twenty-four hours. In a kiln of such a size as this the action is somewhat complicated and difficult to explain. We will endeavour as briefly as possible to indicate the mode of working a Hoffmann kiln with sixteen compartments. Starting from any one section, we will number them for reference from 1 to 16. If we, therefore, take No. 1, we shall have No. 16 on one side of it and No. 2 on the other. Supposing the kiln to be in full working order, No. 16 would be in progress of being filled with green or unburnt bricks, and from No. 1 they would be "drawing" or emptying the burnt bricks. The compartments 8 and 9 would be about in full firing, and the flue connecting compartment No. 15 and the chimney would be open, while Nos. 15 and 16 would be separated by means of a temporary screen of iron plates. The air to support the combustion would thus be entering the kiln through the door of section 1, and, passing through compartments 2, 3, 4, 5, and 6, it would assist in cooling them, and in return take up much of their waste heat. Through the holes in the roof of the 8th and 9th compartments the fireman would be introducing the fuel, and the heat passing from these two compartments would probably have made Nos. 10 and 11 nearly red hot, though no fuel had as yet been put into them. This heated air, in passing through 12, 13, 14, and 15, would be employed in driving off the moisture from the green bricks, the 15th compartment having only been filled on the previous day; the waste heat and steam would then escape from 15 through the flue into the chimney. If our readers have been able to follow us in this description, it will readily be seen that we have here the most favourable condition for economical working; for the heat given out by the brick in cooling is all carried forward and utilised in the firing, and the superfluous heat from the firing is made to "smoke" or drive off the moisture from the unburnt bricks. The mode of loading each compartment does not differ very much from an ordinary circular or flue kiln; it is only necessary in the lower part to leave free spaces among the bricks for the passage of the draught, and to arrange an open hole or fireplace beneath each of the feeding orifices in the top or roof of the compartment. These vertical fireplaces are kept exactly true by dropping a plummet through the opening, and it is customary to arrange a number of bricks in each one projecting slightly forward to serve as ledges on which the coal-slack or dust used as fuel may rest, instead of all falling in a lump to the bottom. In consequence of the admirable way in which the heat is utilised in these kilns, the quantity of fuel for a given number of bricks is extremely small—not more than from 3 to 5 cwt. of slack per thousand, while in the

old form of kiln a consumption of 15 cwt. was not considered excessive.

The Hoffmann kiln is an almost perfect smoke-consumer—indeed, the presence of any smoke is at once a clear proof that some part of the operation is being mismanaged—and it does its work very uniformly, that is, the contents are very regularly and evenly fired. The chief objections which are brought forward against it are its great cost (from £3,000 to £4,000), and the fact that it necessitates a very large and constant make, as it cannot be stopped for a day or two when trade is slack, but must be kept continuously at work. Bricks made in the way we have described can be produced in a shorter time than those used from plastic clay, owing to the shorter time they take in drying. Thus, clay dug on Monday is made the same day into bricks, which would, under ordinary conditions, be dry enough on Tuesday to go into the kiln, and on being bricked up on Wednesday in a sixteen-compartment kiln they would be drawn on the following Saturday fortnight. The bricks made by the dry process, though generally truer and better in form than those made from plastic clay, lack the toughness and strength of the latter brick, and are readily broken by a smart blow with the trowel in setting, especially if they are slightly under-burnt. This seems to be owing to a want of due cohesion between the particles of clay, as the fracture of such bricks looks gritty, like stone, and moreover, their outer layer is often much harder than the interior.

The dry process lends itself very well to the preparation of the so-called concrete bricks, or bricks which rely for their consolidation upon the setting power of lime or cement, and not upon firing. In the neighbourhood of dwelling-houses the burning of bricks gives rise to many noxious gases and smells, not to mention the dense black smoke, and there is no doubt that sooner or later brick-fields will all be banished from the outskirts of inhabited districts. With this probability in view several manufacturers have set to work to discover the best way of making bricks from lime and sand or Portland cement and sand, which might in a few days after making become hard enough to use for building purposes; and owing to the vastly increased resistance of cement concrete made under pressure, it seems likely that this problem is on the eve of being solved. Thus, a mixture of one part of Portland cement and eight parts of sand gauged very stiff, or with a very small proportion of water, on being submitted to a pressure of twenty tons in a mould, set very rapidly, and in four or five days was ready for use. The economical aspect of this mode of manufacturing bricks depends upon the entire saving of fuel, the decreased amount of manipulation which is requisite, and the rapidity with which the article can be produced. All danger in the drying and firing is likewise avoided, and the bricks are all exactly uniform in weight and appearance. The defects of this system are the difficulty of mixing intimately the sand and the cement, the dinginess of the colour, and the weight of the resultant bricks. We think, however, that all these objections may be shortly overcome; and we hope to see concrete bricks before long in general use. It is obvious that the mode of dealing with the cement is the same as we have described for the semi-dry clay.

We may now consider the manufacture of bricks by the plastic process, which, we may add, is by far the more common of the two. For this purpose the clay is usually dug or "got" in the autumn, and allowed to remain in shallow heaps through the winter in order to "fall," though many manufacturers now look upon this as an exploded tradition of the trade. To temper it thoroughly, the clay is passed through horizontal rollers set to various gauges, which break up the hard lumps, and from the rollers it is passed into a pug-mill, where, under the action of knives or cutters, and with the addition of water, it is brought to a waxy consistency. In some machines the clay is forced out of the pug-mill in a stream of suitable size for cutting up into bricks, say ten inches by five inches. This stream of clay is conducted on a series of flannel-covered runners, and is from time to time cut up into slices three inches thick by means of wire cutters mounted in a frame, which can be made to move across and divide the clay into bricks. In other brick machines the clay from the pug-mill is passed into a cylinder, where it is subjected to considerable pressure, and squeezed out into a stream, which is then cut up into bricks by a wire traversing across the clay. In our next article we shall deal with other plastic processes, and some of the many varieties of brick kilns.

APPLIED MECHANICS.—XVII.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

MACHINERY USED IN SAWING TIMBER.

THE CIRCULAR SAW.

Among the most useful pieces of machinery used in the constructive arts the saw takes high rank. Without its aid it would be impossible, or nearly so, to cut up a tree or any large mass of timber into planks, or smaller pieces suitable for the purposes for which they may be required. But powerful as the saw may be in all its variations, from the tenon and keyhole saw to the long lithe blade worked by two sawyers in a pit, the work that is done by it, when set in action by manual labour, is slight when compared with that which is effected by it in its modified circular form, driven with great rapidity by mechanical appliances or by steam or water power.

The circular saw is a disc of thin steel, containing teeth on its circumference. The magnitude of the teeth depends very much upon the character of the wood which the saw is intended to be employed in cutting. They are generally very much larger than the teeth in the ordinary hand-saw. The circular saw is made to revolve with very great velocity, and the wood to be acted upon is brought against its circumference. In order to estimate the relation of the power which the saw exerts to its velocity, we shall enter into details with reference to the small circular saw represented in the next page (Fig. 1). What we have to say with reference to this saw we shall afterwards apply to large circular saws worked by means of steam-engines or water-mills.

C T is a heavy fly-wheel, containing a groove in its circumference for the reception of a band. A B is a treadle, which is worked by the foot. This treadle is mounted on a pivot at A, and at B the connecting-rod B P is attached to the crank C P; and the alternate motion of the treadle thus produces a rotatory motion of the wheel. The wheel must be tolerably heavy, because it is only during the down-stroke of the treadle that the force is communicated to the wheel, and therefore the inertia of the wheel must suffice to carry on the motion during the up-stroke. This arrangement is similar to that already mentioned in the lathe. The band which embraces the fly-wheel passes upwards to a pulley, O. This pulley is very much smaller than the fly-wheel. We shall suppose that the pulley has only one-tenth the diameter of the fly-wheel, and therefore the pulley will perform ten revolutions for each revolution of the wheel; on the same spindle which carries the pulley O the circular saw R is mounted. This saw therefore revolves with the pulley. The saw passes through a slit in the table upon which the block, S, to be sawn is placed. In order to examine the forces and velocities at the different points of this machine, we shall give dimensions to the different parts. Let A B, the treadle, be 2 feet long, and let the pressure be applied at the point D, midway between A and B. Let the crank, C P, be 2 inches long, the diameter of the fly-wheel 20 inches, the diameter of the pulley 2 inches, and the diameter of the circular saw 8 inches. We shall also suppose that the average pressure exerted by the foot upon the treadle is 30 pounds.

The point B oscillates through a space which is very nearly double the length of the crank C P. D moves through half the distance through which B moves, since A D is half of A B. Hence for each revolution of the wheel, the mean pressure of 30 pounds is applied through a distance of 2 inches, and therefore

$$30 \times \tfrac{1}{6} = 5$$

units of work are imparted to the wheel at each revolution.

The circular saw has in its circumference a length of

$$2 \times 8 \times \tfrac{22}{7} = 50 \text{ inches very nearly;}$$

and since a circular saw makes ten revolutions for each revolution of the fly-wheel, it follows that the edge of the saw will move through 500 inches while the power which gives motion to the machine has only moved through 2 inches. Hence the magnitude of the pressure which the margin of the saw is capable of exerting is

$$\tfrac{30}{250} = 0{\cdot}12 \text{ pounds, or nearly 2 oz.}$$

In the use of an ordinary hand-saw, the carpenter is con-

scious of exerting a force of several pounds in sawing a plank which can be cut just as easily and as rapidly by the use of a circular saw when the pressure of the acting parts of the saw only amounts to a few ounces. This difference is to be attributed to the great velocity with which the circular saw moves.

If we make the fly-wheel move round once in a second, the margin of the saw will travel 500 inches in a second, or about 2,500 feet in a minute. Let us suppose that the wood is cut at the rate of 1 foot per minute by the circular saw; then each revolution of the saw will have to cut about the two-hundredth part of an inch. The circumference of the saw contains, we shall suppose, fifty teeth; thus, since in one revolution the fifty teeth have only to cut the two-hundredth part of an inch, it follows that each tooth has only to take a cut of about one ten-thousandth part of an inch. Thus a very small force alone is necessary for the purpose of urging the teeth of the saw to their work. This force is in the case we have supposed about two ounces.

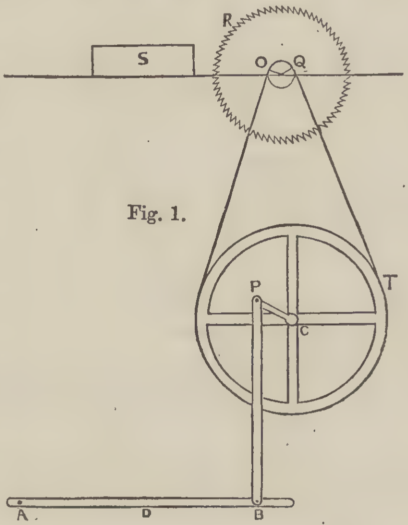


Fig. 1.

The advantage of working at a high speed, with small pressure and small cut, principally depends upon the smoothness and regularity with which the work proceeds under these circumstances. The circular saw itself becomes a sort of fly-wheel, and, by its high velocity, is able to move uniformly, notwithstanding the small changes in the resistance which are never absent from such a process as sawing. In sawing logs of wood into planks a series of parallel saws, which make several cuts simultaneously, are employed. The mode by which the saws are moved is very simple. The several blades are mounted in a frame which moves vertically upwards and downwards in guides. These saws are strained by wedges to the proper degree of tension. Pieces of wood of the exact width of the planks required are placed between each pair of saws, and the whole series is bound together tightly.

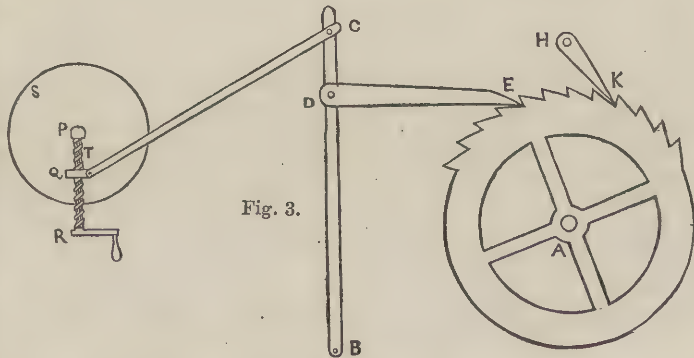


Fig. 3.

The mechanism which gives motion to the frame is shown in Fig. 2. C D is the frame, of which one saw, C D, is represented; A is the extremity of a shaft which carries the crank A B. This crank is attached to the end of the frame by the connecting-rod B C. Thus, as the shaft rotates, the frame oscillates backwards and forwards, and cuts the wood which is brought against it.

Special mechanism must be provided by which this log which is being sawn into planks shall be carried forwards during the operation. We shall first examine into the conditions which must be fulfilled by a perfect apparatus for administering the feed, and then we shall describe some of the different machines which are employed for the purpose. To saw uniformly, it is proper that each tooth should have to make a cut of the same depth, the amount of that depth depending upon the quality of the wood and the magnitude of the log which is being operated upon. The frame C D, and therefore the saw which it carries, do not move uniformly. When the extremity of the connecting-rod is at E, the saw is then at its highest point, and its velocity at that point vanishes. When the crank moves towards B, the velocity of the saw gradually increases, until the angle between the crank and the connecting-rod becomes a right angle; nearly at this point the velocity of the saw is a maximum. As the crank continues its revolution the velocity gradually diminishes, until it becomes zero at the bottom point, H. The crank then ascends through the semicircle H K E, and raises the frame, the saw ceasing to act during this part of the motion. Thus during half the time the machine is working the saw has ceased to act entirely, and during the remainder of the time the action is variable. These points determine the character of the motion which gives the feed. During the up-stroke of the saw the feed must evidently cease altogether; during the down-stroke the feed must be so applied that each tooth of the saw shall have the same cut to make. It is evident that this will not be the case if the feed be uniform during the down-stroke. The velocity of the middle teeth of the saw during the down-stroke is greater than the velocity of the extreme teeth; hence, if the velocity of feed were uniform, each of the extreme teeth would have to take a larger cut than the central teeth, and the work would not proceed with uniformity. The velocity of the feed during the down-stroke must be so regulated as to bear a constant proportion to the velocity of the saw at the same instant.

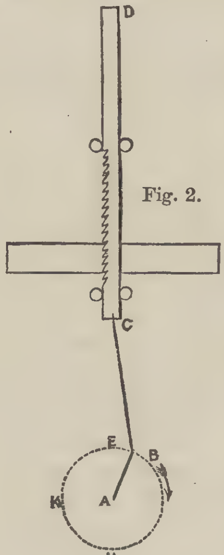


Fig. 2.

We shall now describe some of the different arrangements which are in use for the purpose of regulating the feed, in accordance with the conditions we have determined. The immediate arrangement by which the motion is given to the timber is by means of a pair of rollers, between which the log is tightly held; one of these rollers is acted upon by some one of the different pieces of mechanism which we shall now examine.

The annexed figure (Fig. 3) represents one of the most usual forms of apparatus. A is a ratched wheel, which is connected with one of the rollers by which the wood is advanced to be cut. This ratched wheel is moved by the tooth D E, which is attached to the arm B C, turning around the centre B. It will easily be understood from the figure that when D E is pushed towards the ratched wheel this wheel is advanced, while when D E is withdrawn from the wheel it will fall over the teeth without moving the wheel. It is therefore necessary to provide a reciprocating motion for the arm B C to move the piece D E. P S is a disc which is turned round by the machinery which works the saws, P R is a screw turned by a handle at R, which carries the nut Q. The connecting-rod T C is attached by a pin, about which it can move freely, to the nut Q. When the wheel P S rotates the nut Q describes a circle of which P is the centre. The consequence of this motion of the connecting-rod is that the point C is made to oscillate backwards and forwards, and thus work the ratched wheel.

We shall now explain how this contrivance is able to produce motion of the character which is required for the feed, and

then we shall explain the object of the screw whose bearings are embedded in the wheel. The point C moves in the arc of a circle, of which B is the centre. The distance through which C moves is, however, small in comparison with the length of the arm B C. Hence we may without appreciable error consider that the point C moves in a straight line perpendicular to B C, for a small arc of a circle differs very little from the chord of that circle. Since, therefore, one end of the rod C Q moves in what is practically a straight line, while the other describes a complete circle, the motion of the point C must be exactly similar to that of the frame and saws in Fig. 2. In fact, the frame is moved in a straight line by a connecting-rod, the other end of which describes a circle. It follows, therefore, that the motion of C is similar in character, though, of course, different in extent to the motion which actuates the saws.

The point D moves in a similar manner to the point C. This will easily be proved by drawing a consecutive portion of the rod B C to the position shown in the figure. It will then be found that the old and new portions of the point C form with B a triangle similar to the old and new portions of the point D and the point B. Hence the point D moves backwards and forwards with a motion similar to the movement of the saw-frame and the saws.

By means of the piece D E, the motion of the point D is imparted to the circumference of the wheel A. While E is receding, the piece drops from one tooth to the next, and the wheel remains at rest; this is arranged to take place when the saw is being raised, and is therefore out of action. When the saw descends, the piece D E is moved forwards with a motion which gradually accelerates as the velocity of the saw accelerates, and then gradually comes to rest as the cut of the saw draws to a close. Thus the feed is adjusted so that the work proceeds with the utmost uniformity. The object of the detent H K is to prevent any motion of the ratched wheel when the piece D E is being drawn backwards. Were it not for this piece, vibration or other causes might drive the piece of timber from the saws during the up-stroke, and thus the next cut would be less than the proper amount.

So far we have only described the means by which the right character of the feed is given; the actual magnitude of the feed is determined by the position of the nut upon the screw. The amount by which the timber is advanced at each cut depends upon the number of teeth taken up by the piece D E. This depends upon the distance through which D moves at each vibration, and this again depends upon the distance through which C moves. The length of the path which C describes is equal to the diameter of the circle described by the nut Q. This will easily be understood from Fig. 2. It is there evident that the saw-frame oscillates through a space equal to the diameter of the circle described by the extremity of the crank, precisely similar to the motion of the rod C Q in the present case. The point C describes a space equal to twice P Q. Now, by means of the handle R, the nut Q can be approached to the centre P or withdrawn therefrom; and thus the amplitude of the path described by C is capable of the most complete control. The handle R can, of course, be removed when the adjustment has been made, so as not to interfere with the revolution of the wheel and the motion of the connecting-rod.

The only objection to the use of the apparatus we have described is that great exactness of adjustment of the cut is not attainable. The piece D E can be made to take up any integral number of teeth, but cannot, of course, take fractional parts. This inconvenience may be to a great extent obviated by having the teeth very small and numerous; in this case, though only an integral number can still be taken, yet a nicer approximation can be made to the capabilities of the machine. But a far more elegant arrangement is found in what is known as the "silent feed." By the use of this appliance the feed can be adjusted with the utmost delicacy. In fact, the contrivance is equivalent to a ratched wheel with an infinite number of teeth.

In the present series of lessons we have made many references to the force of friction. This force generally appears as a force of resistance to motion; but not unfrequently this very force is made the means of producing motion. If we have two pieces in contact, one of them may have motion without moving the other piece when friction is absent, while when friction is present the motion of one piece of necessity constrains the motion of the second piece also. Here we have friction as the direct cause of the motion of the second piece. It is this principle which is applied in the use of the "silent feed" for sawing machines.

In Fig. 4, Q is the centre of a wheel which, when the silent feed is used, replaces the ratched wheel which is attached to the roller that moves the timber. This wheel has a rim on its circumference—it is, in fact, part of a cylinder whose axis is perpendicular to the plane of the power, and passes through Q. The object of this rim is to enable the nipping apparatus to pass clear of the spokes of the wheel.

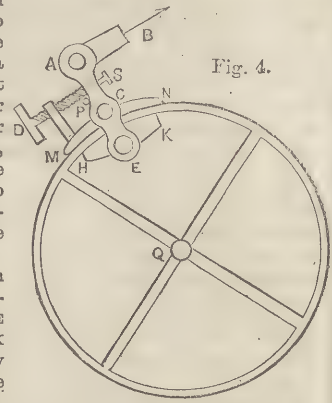


Fig. 4.

M N is a saddle which slides upon the outer circumference of the cylinder; A C E is a lever centred at C. H K is a piece which fits very closely on the inside of the cylinder. A B is the connecting-rod, which is made to move in the same manner as the connecting-rod in the ratched wheel. When A B is moved in the direction pointed out by the arrow, the piece H K is pressed firmly against the inside of the rim, and the friction is sufficient to make the saddle and the wheel move in one piece; thus the motion of the connecting-rod makes the wheel revolve precisely as in the case of the ratched wheel. On the return motion of the connecting-rod, the piece H K unlocks, and the lever A E is met by a stop on the saddle P, which restrains its motion from again locking H K; thus on the return the wheel remains at rest. By means of the screw already described, the distance through which the saddle moves upon the rim can be adjusted with the utmost delicacy, and thus the magnitude of the feed is under the most precise control. S is a stop which is acted upon by the screw D. When S is screwed up, the saddle is unable to lock, and the mechanism is thrown out of gear; this is equivalent to raising the piece D E from the ratched wheel.

A second saddle and friction-piece are fixed upon the rim, so as to discharge the function of the detent H K in restraining the motion of the wheel during the up-stroke of the saw.

The machinery which we have described as used in the sawing of timber contains the principal contrivances to be met with in saw-mills; but space does not permit us to treat of several minor details.

CIVIL ENGINEERING.—IX.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DOCKS.

THE Victoria "London" Docks deserve a special notice, on account of the magnitude and perfection of the works carried out in connection with them. They occupy a position in a direction east and west, across a promontory separating Galleon's Reach on the east from Bugsby's Reach on the west; the original idea in placing the docks in this locality being to afford them an entrance at each extremity, opening into either reach, whereby the entrance and departure of vessels would be greatly facilitated. The original conception has not as yet been carried out, but the land necessary for completing the undertaking has been purchased by the company.

The docks now in operation occupy the western portion of the promontory, and possess a water-area of nearly 100 acres, of which the main dock alone exhibits a magnificent sheet of water of 80 acres, whilst the tidal basin and entrance-lock exceed 16 acres.

The basin and dock together are 4,050 feet long, and 1,050 feet wide at the level of high-water mark. Vessels enter by two pairs of lock-gates from the Thames into the tidal basin, which is separated by a dumb jetty, with a single pair of gates, from the main dock. In the latter are four jetties, projecting 581 feet into the dock on the north side, for the loading and un-

loading of vessels. Each jetty is 140 feet wide, and there is a space of 430 feet between them, with 550 feet of water intervening between the most easterly jetty and the eastern boundary of the dock. By this arrangement quay-room equal to nearly three miles is provided.

The bottom of the basin and main dock is 24 feet below Trinity high-water mark, whilst the depth gradually increases to 25 feet 8 inches in the channel leading from the lock to the basin, diminishing 2 inches on the sill of the inner gates, and then increasing to 28 feet on the sill of the outer gate, and through the entrance into the river; the mean fall of tide at the entrance is 18 feet.

The top of the copings of the entrance and entrance-lock walls corresponds with the level of the old river bank, which protects the marsh-lands in this locality from the overflow of the tide; and this is maintained at the height of 5 feet above Trinity high-water mark.

The soil which was excavated for the formation of the docks consists of a stratum of yellow and blue clays of various thicknesses, altogether about from 5 to 6 feet deep, then a stratum of peat from 5 to 12 feet thick, and then a bed of gravel lying upon the London clay, the gravel varying from 7 to 10 feet in depth. The solid clay was thus found at an average depth of 37 feet below Trinity high-water mark, and 6 inches below this the brick-work of the gate-platforms was laid.

The side-walls of the lock and entrance are throughout constructed of cast-iron piling and plates, backed with concrete, the only omissions being where the brickwork is inserted for the gates. The piling slopes 2 inches in the foot, and the copings opposite the iron pilings are 91 feet apart. There is no slope or batter given to the brickwork, and the walls are 80 feet apart. The dimensions of the lock-chamber are, 326 feet 6 inches long from gate to gate, 80 feet wide at bottom, with 10 feet depth of water on the sill at low water. The piled and concrete walls recommence at the extremity of the brickwork which forms the sides for the entrance-gates, and is carried forward for nearly 400 feet upon the left hand of the entrance, and 160 upon the right hand. We have in a former paper (No. VIII.) alluded to the iron piling and plates employed at Brunswick Wharf, Blackwall. That employed at the entrances and lock-chamber of the Victoria Docks is somewhat similar, and we will now enter into the details of its construction, as being a matter of great importance in marine engineering. The cast-iron piling is formed in bays, which are 7 feet 1 inch from centre to centre of the main piles, the space intervening being filled for a distance of 15 feet from the top by three cast-iron plates, retained laterally by the edges of the main piles which stand in front of them; the space below the plates being occupied by four cast-iron sheet piles, on the top of which the lower plate rests, the lower edge of the plate being formed with a fillet, which overlaps and hides the top of the piles, and holds them in their position. In Fig. 15 we give elevations and sections of the plates and piles. The plates are strengthened at the back by cross-feathers, A A A, and fit one into the other by overlaps as seen at B B in the section. The main piles (Fig. 16) are each in two lengths, the bottom portion being 25 feet long, and 18 inches wide on the face. They are strengthened by two vertical feathers or flanges (C C in the section) at the back, 8 inches deep, 12 inches apart, and 2 inches thick. The upper pile is 12 feet 8 inches long, and 18 inches wide, and is similar in section, but lighter in make. The two fit one into the other, the top portion being cast with fish-pieces, F F, for the purpose, and bolted together through the fish-plates. The sheet piles are in one length of 20 feet, somewhat similar in section, but furnished with a lip, L (Fig. 17), on one side, to overlap the adjoining pile. In the rear of each main pile, and at a distance of 18 feet from it, a timber tie, 20 feet long, is driven to the same depth as the cast-iron pile. Through the head of this tie two wrought-iron rods, 2 inches in diameter, are passed, and secured by washer-plates and nuts. The lower tie-rod is connected with the upper end of the bottom portion of the main pile by means of an eye-bolt passed through the hole H (Fig. 16); and the upper tie-rod with the upper portion of the main pile at a distance of 8 feet above the other rod in a similar manner through the hole H′. The main piles are driven 5 feet into the gravel, and the sheet piles 2 feet 6 inches.

Between the inner gate and the basin, the channel was excavated to a depth of 27 feet 8 inches below Trinity high-water mark, and the bottom puddled with clay to a thickness of 2 feet. The concrete at the back of the iron plates is carried to the same depth as the bottom of the clay puddle, and the entire space between the concrete and the land-ties is filled in with gravel, well rammed. In the lock-chamber the gravel in the bottom was taken out down to the clay, except at the sides where the piles are driven, and here concrete is laid, sloping from the wall downwards towards the centre, the intervening space being filled with clay puddle to the necessary level.

Below the entrance-gate the concrete wall occupies the entire space between the sheet-piling and the land-ties up to a level with the top of the latter, when it is reduced in thickness to about 10 feet, and then carried up vertically. The wharf wall is finished off at the top in front by a stone coping, 18 inches thick, and 3 feet broad.

In consequence of the London clay forming an impervious foundation at a convenient depth under the gate platforms, it was not necessary to use inverts, but ordinary brickwork, in level courses, was employed. A sufficient area for the respective platforms was laid bare down to the London clay, and round these areas a single row of elm sheet piles, 16 feet long, and 8 inches thick, was driven close to a depth of about 6 feet into the solid clay, and within the areas so enclosed the brickwork of the platforms was laid—in the case of the lower gates to a thickness of 8 feet 6 inches in that part of the platform traversed by the gates, and of 9 feet 6 inches in the remaining part; whilst in the case of the upper gates, the thickness of the brickwork is 6 feet 6 inches under the gates, and 7 feet 6 inches in the remaining part. The great object in securing a perfect union between the brickwork and the clay is to prevent the water from getting under the platform and blowing up the brickwork; the sheet-piling around effecting the same object with regard to the side-joints of the brickwork. Upon these admirably constructed platforms, the side-walls are carried up, being built of brickwork 20 feet thick, except where the recesses for the gates are left.

The lock-chamber is connected with the outer channel and the basin respectively by two cast-iron pipes, each 5 feet in diameter, which form the medium for the passage of the water for filling and emptying the chamber. Near the middle of these pipes are placed the paddles or sliding-plates for closing the passages. These paddles are of cast iron, faced with brass, and are lifted and lowered by hydraulic power.

The gates, of which there are three pairs—viz., two to either end of the lock-chamber, and one in the jetty separating the basin from the main dock—are constructed almost entirely of wrought iron; the two former have each a span of 40 feet, and a height of 31 feet, and are very considerably curved, the versed sine of the arc formed by them when closed being 20 feet, or one-fourth of the span. The gates may in general terms be described as consisting of two skins of wrought iron, separated from one another by transverse plates, strengthened with angle-irons. The joints being riveted and water-tight, each gate possesses a low specific gravity in water. The curvature of the inner and outer skins is different, the outer curve being an arc of a circle having a radius of 50 feet, and the inner that of a circle whose radius is 59 feet $9\frac{1}{2}$ inches; the result of this flatness in the inner curve being to make each gate thicker in the middle than the ends, the ends being 24 inches apart between the skins, and the middle 36 inches apart. The skins are kept apart by a series of horizontal plates, varying in vertical distance from each other, being nearer at the bottom, and increasing in distance towards the top. The bottom plate is three-quarters of an inch thick, and to it is secured the timber which meets the shutting-sill, the latter being of cast iron. The other plates are half an inch thick, and are connected to the skins by T and angle irons. The interior of the gate is further strengthened by vertical plates, which pass continuously from the top to the bottom, intersecting each horizontal plate. There are two of these vertical plates in each gate, thus dividing the entire gate into three nearly equal vertical divisions, irrespective of the horizontal divisions. It is obvious that by this arrangement the gate becomes a structure of exceeding strength, combined with great lightness; and the large space which exists between the various diaphragms permits of access to all parts of the interior for cleaning, repairing, etc., by means of man-holes.

which each compartment is provided with. Covers also are provided for the man-holes, and thus the requisite amount of weight or power of flotation is given to the gates by the introduction or withdrawal of water. The thickness of the skin varies from about three-quarters of an inch at the bottom to three-eighths of an inch at the top. It consists of wrought-iron plates, riveted together, the plates being placed vertically; every joint having a strip of iron both outside and inside, to ensure its being thoroughly water-tight. The heel and mitre posts are of timber, strongly bolted to the vertical plates which form the ends of the gates. Great care had to be taken to prevent leakage into the gates through the bolt-holes. The gates are turned by hydraulic power, applied through the medium of a chain $1\frac{1}{4}$ inch diameter, communicating a maximum force equal to about 7 tons per square inch of chain section. The chains are attached to the gates at a point 2 feet above low-water mark, passing through an eye-bolt having a sectional diameter of $2\frac{1}{2}$ inches, with an attachment to both skins.

The pivot-cross upon which each gate rests and turns consists of a strong cast-iron cross, each arm being 5 feet long from the centre, cast hollow upon the under side, and having oak timbers 15 feet long fixed to each arm, the arms being securely fixed to the brick-work of the platform by 2-inch bolts, passing down through 8 feet of solid brickwork into thick cast-iron plates embedded in it at that depth, whilst two of the arms of the cross are built upon by the side-wall of the lock-chamber. The pivot itself is of cast-iron, 6 inches long, and accurately turned to a diameter of 11 inches.

The shutting-sill, which is of course curved to correspond with the inner curvature of the closed gates, is composed of eight cast-iron segments. Its section is that of angle-iron, 2 inches thick, but varying in height and breadth from 12 inches and 18 inches in the centre to 21 inches and 27 inches respectively at the ends. At the extremities, the sill is bolted to the pivot-cross. At every 2 feet there is a back feather uniting the extremities of the angle, in order to strengthen it. The sill is bolted down to the brick-work by bolts passing up through it from a cast-iron plate laid in it at a depth of 8 feet at the time of building. The bolts are 2 inches and $1\frac{1}{2}$ inches in diameter, and each segment is secured by ten of the former and five of the latter.

The position of the roller upon which a gate rests must be determined by a consideration of the proportion of the weight of the gate it is intended to bear. If it be placed quite at the extremity of the gate—that is, near the mitre-post—it is obvious that the weight of the gate is fairly divided between it and the pivot; and the nearer it is placed to the latter, the greater is the proportion of weight resting upon it, until when it lies in the intersection of the vertical planes passing through the centre of the pivot and the centre of gravity of the gate, in which position it bears the entire weight of the gate. If the gate were a *straight* gate, the roller would naturally be fixed somewhere *under* the gate; but in the case of a curved gate, there are other considerations involved, and it has been found desirable to place it outside the outer curve. The rollers upon which rest the gates we have been speaking of are of cast iron, 7 inches wide, and 32 inches diameter, and, by an ingenious arrangement, can at any time be removed for repairs. The roller-path is also of cast iron, $4\frac{1}{2}$ inches wide and 8 inches high, having the section of a bridge rail, and bolted through 15-inch wide timber to cast-iron plates set in the brickwork.

The anchor or supporting piece for the upper pivot of the gates is of cast iron, in the form of a sextant, being 11 feet from the centre of the pivot to the outer curve. It is bolted down to immense bed-plates of iron set 10 feet deep in the brickwork of the side-wall. The strap which secures the gate to this casting is of wrought iron, 7 inches deep, and 2 inches thick in the arms, but increasing to 5 inches near the centre, at the part which suffers from the friction of the axis. This axis is 18 inches in diameter, made of wrought iron, and riveted to a $\frac{3}{4}$-inch iron plate on the top of the gate. The strap is adjusted in the usual manner by keys.

There is a slight difference in the size of the lower gates as compared with the upper and inner gates, but they are all of substantially the same character in the mode of construction. The gates which enclose the lock-chamber are worked by hydraulic power, which is not the case with the inner pair, the advantage of hydraulic power being seen from the fact that the lock-gates can be opened in $1\frac{1}{2}$ minutes; the latter have the sluices in the gates themselves, and not in the side-walls.

Upon each of the five jetties alluded to in the early part of this paper is constructed a substantial warehouse, comprising an upper floor, a ground floor, and vaults, of nearly an acre each in extent, being 500 feet long and 80 feet broad; and upon the space intervening between the roof of the warehouse and the edge of the jetty are placed hydraulic cranes, nine cranes to each jetty. The most powerful crane upon each jetty is at the extremity, and is capable of lifting 5 tons; the others are 2-ton cranes. The side-walls of the jetties are vertical, and consist of cast-iron piles placed 7 feet apart from centre to centre, with 14-inch brickwork, set in Roman cement, filled in between the piles. The brickwork panels are inverted arches, the concave side towards the water, the inner surface being backed first with concrete and then with clay. Each cast-iron pile is 35 feet long, and weighs $1\frac{3}{4}$ tons, and is connected with its corresponding or opposite pile upon the other side of the jetty by two tie-bars of 2-inch round iron and 140 feet long, fixed to the piles at 5 feet and 17 feet respectively below the head of the pile; the piles enter the ground 4 feet below the bottom of the dock. The foundations of the jetty walls are of concrete, 3 feet thick, carried up one foot above the bottom of the dock, and upon this the brickwork is laid. The top edge of the wall is covered with a cast-iron piping, bolted down to the heads of the piles.

The entire dock possesses 145 hydraulic cranes, the necessary pressure being obtained by two 60 horse-power steam-engines, consuming on an average 17 tons of coal per week. In order to convey the water-pressure from one side of the dock to the other, a culvert is constructed under the entrance from the basin to the lock-chamber, terminating at each side in a well; in this culvert the water-pipes are laid, the same culvert being made available for telegraph-wires.

MAIN PILES.

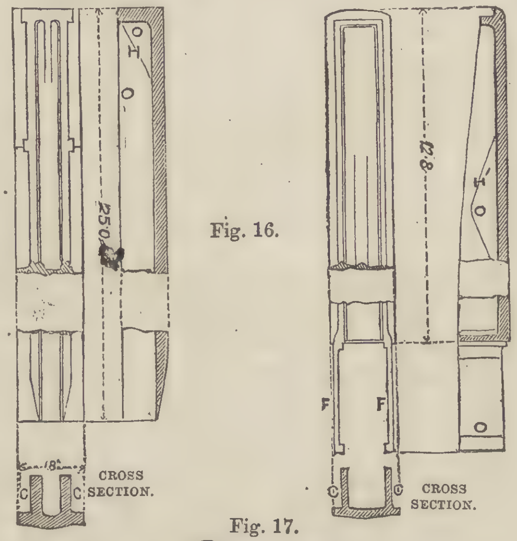


Fig. 16.

Fig. 17.

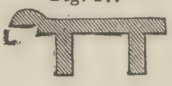
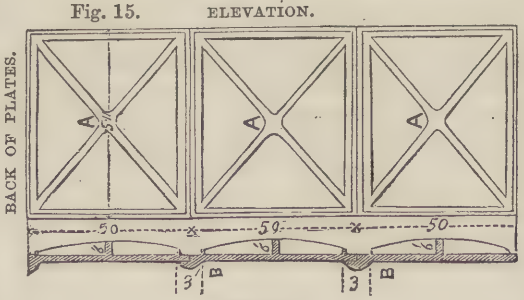
SECTION OF  SHEET PILE.

Fig. 15. ELEVATION.



SECTION.

MINING AND QUARRYING.—X.

BY GEORGE GLADSTONE, F.C.S.

IRON.

REFINING — FORM OF REFINERY — PROCESS — QUALITY OF FINER'S METAL—PUDDLING—THE FURNACE—PROCESS —QUALITY OF PUDDLED BALL.

WE have now to deal with some very important operations for converting the crude iron into a malleable article, and to which about two-thirds of the metal produced annually have to be subjected, the only use of pig-iron as such being for foundry purposes. The special qualities which render iron so pre-eminently useful are only brought out by the processes which have now to be described.

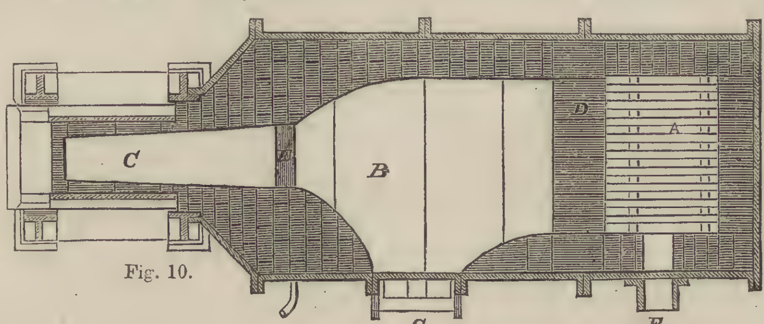


Fig. 10.

The first step is *refining*, and then *puddling*. There are modifications of the second, by some of which the first can be dispensed with; these are of recent introduction, and have not yet superseded the older plan.

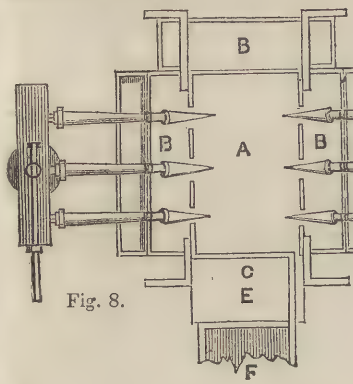


Fig. 8.

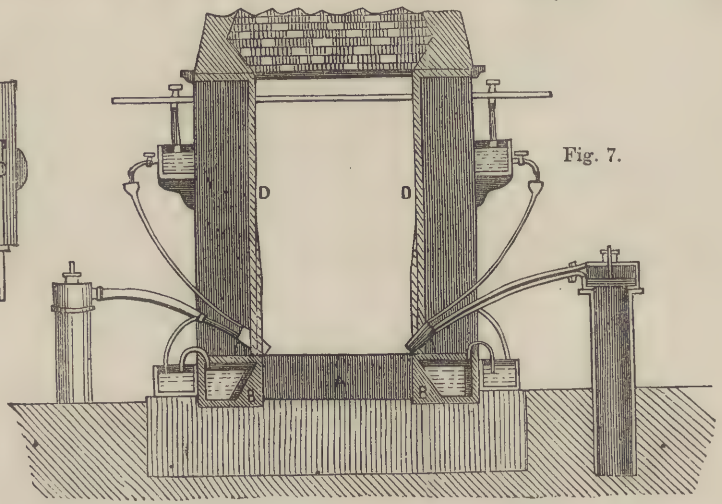


Fig. 7.

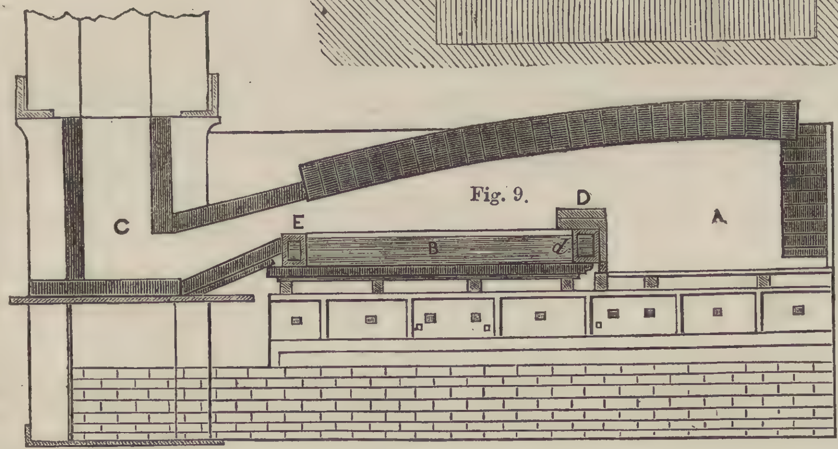


Fig. 9.

Refining.—The object of this process is to remove by oxidation the foreign ingredients which are present in all crude iron, and which were shown in the preceding article to be deleterious to the metal. The refinery or running-out fire will best be understood by reference to the accompanying diagrams (Figs. 7 and 8), representing a sectional elevation and ground-plan of one of these furnaces. It will be seen to consist of a flat hearth, A, with six water-twyers pointing into it. The walls of the hearth at the sides and back consist of three hollow iron troughs, B, B, B, through which cold water is made to flow continually; the front wall being a solid iron plate, with a tap-hole, C, at the bottom of it. The uprights, D, D, in the two sides are made of iron, and support a chimney, but the front and back are movable, the iron plates of which they consist being hung as folding doors. The floor of the hearth and the sloping piece E are protected by a coating of sand; and F is the running-out bed—a long, shallow mould made of iron.

The fuel used in refining is either the purest coke that can be had, or else charcoal; and the blast is supplied cold. The hearth is filled with coke, which is thrown in through the door at the back; upon this about 20 to 22 cwt. of pig-iron are laid; and upon this again more coke is then heaped up. Fire is applied, the doors closed, and the blast turned on. In the course of about an hour and a half the iron has melted and run to the bottom, but the twyers being pointed downwards upon the surface of the metal at a considerable angle, the liquid iron is kept in active motion, and the whole is then subjected to the oxidising influence of the air. In the course of another half-hour the furnace is ready for tapping, when the iron and cinder, or slag, flow out together into the running-out bed; the latter, being of lighter specific gravity, rises to the surface; and the cooling is expedited by throwing cold water upon it. The application of the cold water not only does this, but it facilitates the separation of the cinder, and also renders the iron more brittle, a matter of some consideration, as it has to be broken up into small pieces before being put into the puddling furnace.

The refined iron, or finer's metal, is no longer grey, having parted with the greater part of its carbon; it should now be compact, and almost silvery in lustre. During the process a portion of the carbon and the sulphur has been oxidised and dissipated by volatilisation, and the silicon has combined with a portion of the iron, forming the cinder. Thus a white pig-iron,

containing 1·27 per cent. of silicon and 0·93 per cent. of sulphur, has yielded refined metal containing only 0·14 per cent. of the former and 0·52 per cent. of the latter. This gain in the quality of the iron is not attained without a considerable loss in weight, which varies from 10 to 17 per cent., though the iron and cinder together will exceed the weight of pig-iron operated upon. Thus a charge of crude iron of 2,498 lbs. will yield 2,240 lbs. of refined metal and 325 lbs. of cinder, showing an increase of 67 lbs. due to the absorption of oxygen, and to the taking up of some earthy matter from the fuel, and sand from the floor of the hearth, all of which must be looked for in the cinders, together with the iron which has been lost. An analysis (of which the following cinder from Dudley is a specimen) will confirm this. It contained—

Protoxide of iron	61·2
Silica	27·6
Alumina	4·0
Phosphoric acid	7·2
	100·0

This analysis also shows that the iron from which it came has also been relieved from the presence of a large per-centage of phosphorus. A slag containing so large a quantity of metallic iron is, of course, not wasted; but is re-smelted or used for other purposes.

Puddling.—The finer's metal now passes into the hands of the puddler, who employs another furnace of special construction. It is made upon the reverberatory principle, as shown in Figs. 9 and 10, which represent one of these puddling furnaces of modern type, in ground-plan and elevation. It will be seen to consist of a fire-place, A, with a hearth, B, and flue, C, separated by the bridges D and E. The fuel is put into the fire-place through the aperture F, and the iron into the hearth by the larger one at G. This is closed with an iron door lined with fire-brick, which can be raised at pleasure by a lever and chain; and the top of the flue is provided with a damper which can be regulated in the same manner. Through a small opening in the lower part of the door G, the puddler introduces his long iron bars (the rabble and the puddle) with which he manipulates the iron. The former is a wrought-iron bar, about 8 feet long, rounded at the end held by the puddler, with a piece of flat iron 2½ inches broad, and set at right angles with the rod, at the other. The puddle is rather lighter, with a bevelled edge at the end, like a dull chisel. In this furnace the sides of the hearth, as shown as E and *d*, are made of hollow iron tubes, through which a stream of water is made to pass to keep them cool. The bottom of the hearth is now always made of plates of cast iron, on the under side of which the air is allowed to circulate freely, with the same object. The floor and sides of the hearth are covered with a bed of cinder called "bull-dog," either from previous puddlings or from the refinery, and plastered over with a paste or "fettling" made of red hæmatite or other oxide of iron. Immediately below G is a smaller opening connecting with the hearth, which is called the tap-hole. The furnace being quite separated from the hearth by the bridge, coal is generally used as the source of heat.

The operation of puddling, called by the workmen "a heat," occupies from an hour to an hour and a half. About 4½ to 5 cwt. of iron are puddled at each heat. Sometimes refined metal is used alone, that is, when the best qualities of iron are to be produced; at other times it is mixed in variable proportions with ordinary pig-iron. Some hammer-slag or mill-scale is added, which is all the better if it has become a little rusty, the object of it being to supply an additional quantity of oxygen. The refined and pig-iron having been broken up into small pieces, is piled up round the sides of the hearth; the fire is got up to its full heat by raising the damper, and it is left for about twenty minutes. By that time the iron is just beginning to melt, and the furnace from this time onwards requires the constant attendance of the puddler and his assistant. The temperature of the furnace has to be carefully attended to; and the iron has to be continually stirred and worked with the rabble, so as to bring all parts of the charge to an equally pasty condition. This occupies about a quarter of an hour, during which the damper is regulated so as to prevent the iron from becoming too fluid, when the "boiling" commences, and a full heat is again supplied. This apparent ebullition is due to the combination of the carbon in the iron with the oxygen supplied by the hammer-slag or scale, and formation of carbonic oxide, which is volatilised, and causes the iron to swell up in its efforts to escape. Stirring is kept up continually—the boiling gradually ceases, and presently the puddler finds the iron beginning to "come to nature," indicative of the process being complete. This is known by the iron becoming sticky and working heavy, the cinder separating from it in a very liquid state. Any further oxidation of the iron must now be checked, or a loss of metal would be the result, and the damper is therefore let down. The puddler has now to work up the iron into balls of about 80 pounds each, which are withdrawn from the furnace as soon as made. The cinder is finally allowed to run out at the tap-hole.

The effect of the puddling is still further to remove the carbon, silicon, sulphur, phosphorus, and other impurities of the pig-iron; the tap-cinder drawn from the puddling furnace being very similar in its composition to that which comes off in the refinery. When the raw pig-iron is puddled the quantity of cinder produced is inconveniently large, and if none but refined metal be used, the want of a little is sometimes felt; a mixture of the two generally works very well. In order to ascertain with more precision the nature of the chemical action during the puddling, experiments have been made by drawing samples at different stages of the process, and analysing the metal. The pig-iron operated upon was composed of the following:—

Carbon	2·275
Silicon	2·720
Phosphorus	0·645
Sulphur	0·301
Manganese and aluminium	traces
Iron	94·059
	100·000

The first sample was drawn forty minutes after it had been put into the puddling furnace, and was analysed for the carbon and silicon; the succeeding samples were drawn at various intervals, and similarly analysed, the whole series being as under:—

40	minutes,	2·726	per	cent. carbon,	0·915	per	cent.	silicon.
60	,,	2·905	,,	,,	0·197	,,	,,	
65	,,	2·444	,,	,,	0·194	,,	,,	
80	,,	2·305	,,	,,	0·182	,,	,,	
95	,,	1·647	,,	,,	0·183	,,	,,	
100	,,	1·206	,,	,,	0·163	,,	,,	
105	,,	0·963	,,	,,	0·163	,,	,,	
110	,,	0·772	,,	,,	0·168	,,	,,	

at which time the puddling was complete. It will be seen that nearly all the silicon is driven off at an early stage of the process, but that for some unexplained cause there is during this same period an actual increase in the quantity of carbon; the final result, however, is that the puddled ball only retains about one-third of the quantity contained in the iron at the commencement of the operation. The increase of carbon at the earlier stages has been observed by other experimenters. The greater part of the phosphorus and a little of the sulphur passes into the cinder, as will be seen by the following analysis of the tap-cinder resulting from the experimental operation detailed above:—

Silica	16·53
Protoxide of iron	66·23
Sulphide of iron	6·80
Phosphoric acid	3·80
Protoxide of manganese	4·90
Alumina	1·04
Lime	0·70
	100·00

The operation of puddling as ordinarily conducted is a somewhat expensive one, as the furnace itself only lasts about six months, even when repaired weekly; and a large number of these are required, 25 tons per week being the maximum output of each furnace. The consumption of coal is about equal in weight to the iron produced; and there is an average loss in weight during the process of about 10 per cent. of metal. In addition to this the cost of labour is high, as the work of the puddler and his assistant is exceedingly severe: the prospect of very high wages is consequently necessary in order to induce men to learn the art, especially as it is one in which proficiency is only acquired after long practice.

Before considering the treatment to which the puddled balls are subjected to convert them into bars, one or two other plans of producing them must be described, which will be taken up in the next article.

OPTICAL INSTRUMENTS.—XI.

BY SAMUEL HIGHLEY, F.G.S., ETC.

LANTERN DEMONSTRATIONS (*continued*).

IN *literature*, the memory may be assisted, by corresponding illustrations, to recall types of the peculiarities of style of that "best of all good company," the great writers of all ages. Thus many "half hours with the best authors" might be advantageously spent in the school-room; and where poetry has been set to music, the notes of the tune might be projected on the screen, so that a large class may join in unison.

Magic lantern slides in the ordinary way are kept in boxes, but I regard this as great waste of educational material. If the slides represent natural history subjects, they should be placed in the museum-cases beside allied objects for every-day inspection, care being taken to fix them at such an angle, that light is reflected through them by aid of white paper placed beneath; or by mounting the slides in long frames, backed with ground glass, they may serve as appropriate borders to the windows of any scientific or educational institution.

The advantages claimed for lantern demonstrations are that the most important optical laws, together with many other physical experiments, can by their means be strikingly illustrated, and by the employment of photographically produced slides, a wide range of subjects can be pictorially illustrated on a large scale, in a cheap and efficient manner; that such delineations are truthful to Nature and abound in detail, to an extent ordinary hand-painted diagrams cannot compete with; that when taken direct from Nature or from artistic productions, correct as to the rendering of light and shade, the large and impressive image when projected on the screen stands forth with perfect stereoscopic effect, so that the lecturer is enabled to fix the attention of his audience upon the subject he is describing in a manner not attainable with the ordinary tiers of small paper diagrams, over which the eyes of students too often listlessly wander, while from the magnitude of these lantern pictures, the most microscopical details can be made distinctly discernible even in the largest lecture-hall; that by thus appealing to the eye, or "sight knowledge," we do the next best thing to showing the objects of the discourse themselves, and so establish a system of artificial memory, by aid of which we can teach many subjects quicker and better than the most impressive verbal description, *unillustrated*, could ever attain to, and in a manner not so likely to pass out of mind, a matter of the greatest consequence when a wider range of knowledge is expected from educated people at the present day; that the educational value of such coloured transparent diagrams need not cease with their exhibition in the lecture-room, for they may be used as museum specimens or window decorations. In conclusion, I would say, it is desirable that every exploring expedition should be accompanied by its official photographer; that every national museum, hospital, and astronomical observatory should have its appointed photographic operator; and then the hoped-for time may come, when we can, in systematic manner, place the records of scientific travel, the transcripts of Nature's treasures, mementoes of fell disease, and the self-depicted aspect of the heavens, upon the screens of our lecture theatres, so that we may take our students over the world, or into the depths of space.

SOURCES OF LIGHT.

The means of securing a beam of light of various degrees of intensity, size, and physical properties, is not only essential to the optical experimenter and demonstrator, but also to the operator in several branches of trade. First in rank, as to intensity and physical power, stands sunlight; then in order, the electric light, the lime-light, the magnesium and zinc lights; then Argand lamps fed with petroleum, paraffine, ozokerite, oils, and gas impregnated with hydro-carbon vapours, chlorochromic acid, bisulphide of carbon, magnesium ethyle, etc., down to candles and the artificial star.

I shall proceed to describe a type of these several sources of light, always selecting what, to the best of my judgment and experience, I consider the simplest and best arrangement; as much may be attained in the construction of philosophical instruments by the simplification of parts.

The Solar Reflector.—This arrangement enables us to reflect the solar ray into any piece of apparatus or room, suitably situated, we wish to illuminate with a powerful beam of light, and to keep the rays on a fixed spot. To the photographer this arrangement is invaluable for the production of "enlargements" from small negatives of portraits, landscapes, etc., as no known light is so photographically energetic as that derived from the sun. By experimentalists, and those engaged in teaching science, much may be done with the solar reflector, where the trouble and expense of employing artificial sources of light of great intensity would be regarded as a drawback to frequent work. Its construction involves two adjustments, one of inclination, the other of rotation, so that the sun may be followed in its course, and that its rays may be reflected constantly in one direction.

Some years ago this arrangement was much used for microscopic demonstration, but the lime-light and electric lantern rendered its use, to a great extent, obsolete; and its resuscitation is due to photographic requirements, for while the latter sources of light can be brought into play at any desired moment, the solar reflector can only be employed when the sun shines, a matter of great uncertainty in this country.

The old-fashioned arrangement is shown in Fig. 31. A clamped board, the size of a suitably situated window, is rabbeted to fit the frame closely, so as to exclude all light at the edges, and is kept in place by thumb-screws or wedges. In the centre a round hole is cut, of a size proportionate to the apparatus to be used, which is screwed into a flange attached to the inner or room side of the board. To the outer side of the carrier-board a disc of wood or metal is attached by a suitable counter-sunk fitting to the central aperture; this disc carries on projecting arms a long narrow glass reflector. This disc can be rotated from inside the room by means of a handle that works through a curved slot in the carrier-board, by which motion the mirror can be made to follow the course of the sun, while the proper inclination is given by means of an endless screw working on a racked wheel attached to the axis of the mirror. Some practice is required to keep the beam central, or in one constant direction, as by this arrangement there is a tendency for the mirror to move in jerks. To obviate this defect it is better to effect the rotation by means of a pinion acting on a racked flange (that takes the place of the counter-sunk fitting) connected with the outer disc. The pinion may be turned by a large milled head, or by a lever arm that fits the pinion by a square key-head, by which a more equable motion is secured.

A simpler, cheaper, and better reflector may be thus constructed, and is shown in Fig. 32. A carrier-board, B B B, has a rabbet cut round its edges, by which it is fitted light-tight to a window-frame. About the middle of this board a round aperture is cut to admit the reflected light into the operating-room, and on the inner side of this a brass flange, *ff*, is fitted, into which the condenser, or other apparatus, can be screwed. Below this aperture a rotating brass arm, R, fits with a smooth and even action (by aid of a clamp, C), on to which the mirror elevator (or depressor), E, is hinged at H. This elevator is a square brass arm, from which projects, at a right angle, a curved limb, pressing against a stout screw, S, that works through the axis of the rotating arm R; and it will be seen that as the screw S is turned outwards or inwards, so the arm E will be raised or depressed. The mirror M is fitted in a metal frame, and can be fixed to the arm E by means of a binding-screw, *s*, fixed to the back of the mirror-frame. The rotation of the mirror is effected by a long lever arm, L, that fits by a square key-head on to the rotating arm R. This arrangement allows of several mirrors being used for various purposes—viz., an ordinary mirror of *thin* glass silvered at the back, or a speculum made by depositing silver by the processes of Liebig and Petitjean on a surface of glass worked parallel, or a black mirror, made by roughing the back with emery, and then coating it with asphalte varnish, in which a portion of india-rubber dissolved in benzole (to give elasticity and prevent cracking) has been added. Such a mirror gives a clear, bright image of the sun, and light enough for most experiments, and when set at the proper angle gives a beam of polarised light;

or when a powerful beam of polarised light is required, the mirror may be composed of several sheets of thin, even glass placed one over the other, forming what is technically termed a "polarising bundle;" or when a soft light is required, as in photo-micrography, a "white cloud" mirror may be employed, which is made of a sheet of opal glass, in some cases the rough surface, in other cases the polished or plate-glass side being placed uppermost to reflect the light. These mirrors must be made long in proportion to the diameter of the condenser employed, and somewhat wider than the aperture into which it fits.

I may here state that it is better to mount any necessary apparatus on a stand, independent of the reflector and its condenser, so that should the latter be shaken by the wind in a manner to threaten the result of an experiment (as in photographic work), the two parts can at once be isolated by interposing a screen; and it also allows of greater freedom of action in disposing appliances and getting to the several component parts of any complicated arrangement of apparatus.

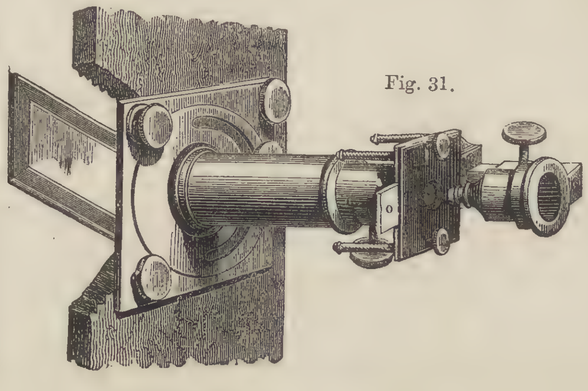


Fig. 31.

The Heliostat.—In the instrument above described all the adjustments are made by hand, and where the experiments are intermittent they answer the purpose, for a practised operator can keep the light central with the axis of any optical arrangement sufficiently long for such purposes; but when it is necessary to keep the cone of light (concentrated by a condensing lens from the reflecting mirror) *absolutely* central for a lengthened period on a fixed spot or direction—as for certain astronomical purposes, delicate physical investigations, and photographic enlargements—then the requisite adjustments must be produced automatically (self-acting). To effect this, motion is imparted by a "driving clock," so that the axes of the several parts of the adjustable mirror may, for twelve or twenty-four hours, turn with a determined velocity; and definite positions are assigned to the component parts of the arrangement, which are deduced from the same laws that regulate the motion of the earth about its axis. Such instruments are called "heliostats."

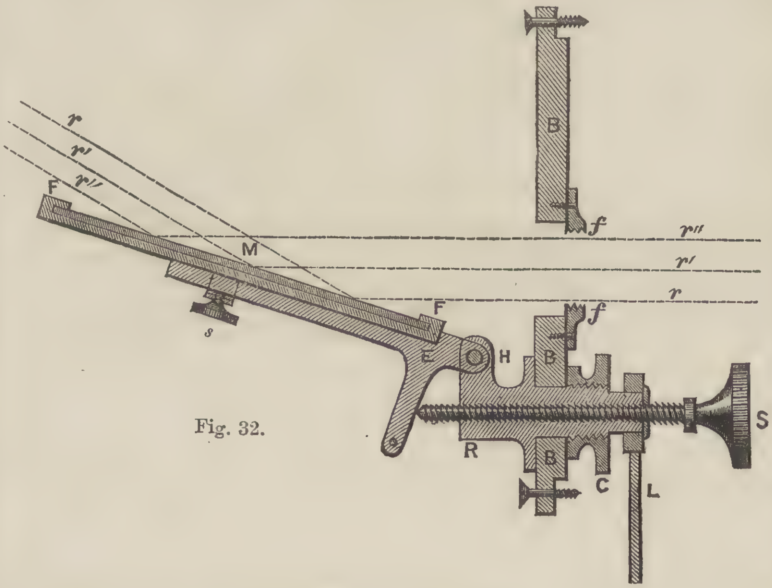


Fig. 32.

The sun, as we know, follows a path which varies incessantly in different countries and at different periods of the year; a perfect heliostat ought, therefore, to be adjustable for all latitudes and for all seasons, and then slowly move in such a way as to make allowance for the apparent motion of the sun, and reflect the light received from it in any direction whatsoever at the will of the operator, and for as long a period as he may desire. The contingencies of this problem are met in the exquisite arrangement of Silbermann, but his heliostat is more complicated and costly than is necessary for most practical requirements; as a heliostat is generally used in a fixed locality, and the reflected beam is usually required in a horizontal direction, consequently adjustments for varying latitudes may be dispensed with, and the arrangements for inclination and centreing greatly simplified. The two most useful heliostats for practical purposes are those of Fahrenheit, as modified by Monckhoven, where a large beam of light is required, say from eight to nineteen inches in diameter, and which can be used as well on the 21st of December—the time at which the sun, in this part of the world, is at its lowest—as on the 21st of June, when the sun is at its highest; and the arrangement of Colonel Woodward, as modified by Dr. Maddox, where a small beam only is required for refined experiments and operations.

The following description is given by Dr. Van Monckhoven, in his treatise on "Photographic Optics:"—

"The table N (Fig. 33) is of turned and polished iron. It is supported on three screws, one of which is seen at O, and presents at its centre a conical fitting, about which turns the piece L M, capable of being made fast to it by tightening the screw *a*. This table is rendered horizontal by means of a good spirit-level.

"The support, J K L M, is of iron. The arc, J K, necessary for the adjustment for latitude, is movable, but is fixed by the maker to the latitude for which the instrument is required. No attempt, therefore, must ever be made to disturb the setting, J K.

"To the piece J K L M is fixed the arm-rest in which the axis A turns, as the figure sufficiently explains.

"The axis, A, is of steel, fixed by a screw to the arm-rest, P Q, and rests upon the brass screw, B, which serves to bring the several pieces into position. The screw B is made fast by a side-screw. The parts of the axis touching the bearings must be always well lubricated with a mixture of paraffine and oil.

"The toothed circle, C, is fastened to the axis by a screw, of which the thread runs the reverse way, so that it may not get loose by the rotatory movement of the axis. This screw also is securely fastened. The wheel C is divided into 360 teeth, and must be kept clean by means of a brush passed over it every day in the direction of the length of its teeth.

"The horary circle, D, is divided into hours from six in the morning to six in the evening, then into parts of twenty minutes each, and lastly, into others of four minutes each, and is fixed on the axis by an hexagonal nut, which can be tightened by the hand. The index, E, slightly movable, serves to indicate the time on the horary circle, and has, for this object, a line engraved with a diamond on its upper part.

"The collar, I, works in a groove cut in the axis, A, and can be made one piece with the axis by tightening, or be left to turn freely about the axis by loosening the screw I, which must be handled gently, and never screwed up very tight. This collar terminates at its lower part in a rod, constantly pressed towards the letter J by a spiral spring. A screw, J, therefore, fixed in an arm-rest, which is attached to the immovable part of the heliostat, and which also carries the spiral spring, enables the collar to be moved in one direction or the other (and conse-

quently the axis A, if the screw I is fast) by very small degrees at a time.

"The arm-rest, P Q, is of iron. At one end it carries a counterpoise, Q, which serves to balance it about the axis A; and at the other an index, P, and an adjusting screw, T U, of which we shall speak presently.

"The mirror, S R, is octagonal, of finely silvered glass. It is mounted in a frame of polished ebony, and has at its two extremities two pivots of polished brass of exactly the same diameter, and with their imaginary axis passing through the reflecting surface of the mirror, and at right angles to the index, X Z, and to the axis, A. These pivots revolve on the arm-rest, P Q, on Y-shaped bearings, and are kept in place by plates of brass.

"The declination-circle, P, is fixed on one of the pivots and divided into half degrees. When the zero of the graduation is brought opposite the index, the surface of the mirror is exactly perpendicular to the axis A—an adjustment made by the maker, and which must never be deranged in dismounting or shifting the index. In the position of the circle shown in Fig. 33, the circle must be read to the right of the zero in winter (from September 21 to March 21), and to the left of the zero in summer (from March 21 to September 21).

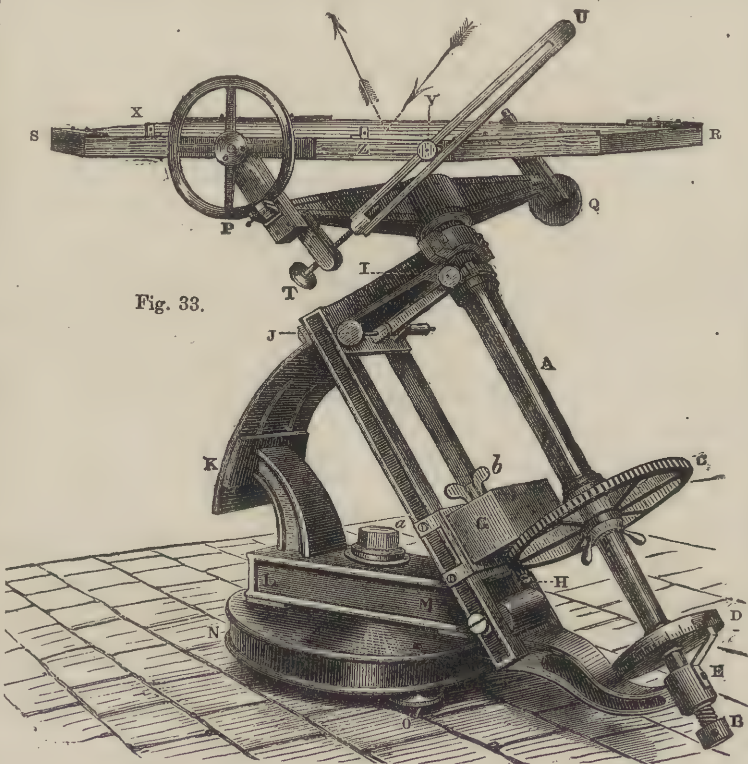


Fig. 33.

"The index is formed of a movable plate of brass, which can be applied to the division of the circle, or removed from it by pressing on the lower part. A single line traced on its upper surface serves to indicate the division of the declination-circle; and as the half and even the quarter of each of them, corresponding to $\frac{1}{4}$ or $\frac{1}{8}$ of a degree (15 or $7\frac{1}{2}$ minutes of an arc), can be very well estimated, this amply suffices for the adjustment of the instrument. It is necessary, however, to be well practised in reading the circle, or better still, to get assistance from some one accustomed to this kind of readings, which besides requires to be done but once for all.

"The bar, U T, consists of a slide-rod, capable of forming one piece with the mirror by tightening the screw V. An adjusting screw, T, attached to the arm P Q, allows, when the screw V is fast, of the mirror being moved very small distances at a time.

"The two sights, X, Z, are squares of brass plate, placed at the sides of the wooden mounting of the mirror, each being pierced by a small hole. Further, the sight X bears on its surface, facing the opposite sight, two lines perpendicular to each other, traced with a diamond, one being parallel to the surface of the mirror.

"When the sights, X, Z, are brought in a line with the sun, a thread of sunlight is seen proceeding from the aperture in the sight Z, and falling on that of the sight X, where it forms an image of the sun. In performing this operation we are guided by the shadow of the sight Z, which ought to fall parallel to the wooden mounting of the mirror. The hand should be held behind the sight X, in order to bring the shadow of the other sight more easily upon the first.

"The clock-work is enclosed in a brass box, G, and is wound up by the key *b*; it goes ten hours, and communicates its motion to the wheel C by its pinion H.

"The clock-work is fixed to the immovable part of the heliostat by four screws, but by slightly loosening the two inferior screws and lowering the clock-work, the pinion H is thrown out of gear. The pinion H can at pleasure be put in or thrown out of gear with the clock-work by tightening or opening the nut H. If it is unscrewed, the axis, A, can be slowly turned, and then the pinion is seen to revolve rapidly. If it is screwed up, the clock-work immediately acts on the toothed wheel C, so as to make it perform a complete revolution in twenty-four hours. Keep the open part of the box under the key, *b*, covered by a brass plate, to prevent dust from getting into the clock.

"*Management of the Heliostat.*—Wind up the clock-work, loosen the screws V, I, H, take hold of the mirror at R, and give it its proper direction, about which we shall speak presently; when this is very nearly effected, tighten the screws V and I, and adjust the mirror by the screws T and J to give it its correct position; then immediately close the nut H, and loosen the screw I, and the mirror will obey the clock-work.

"*Setting the Heliostat.*—Make the table, N, horizontal by means of the level; keep the screws *a*, V, I, and H loose, after having wound up the clock-work.

"Begin by rendering the mirror horizontal by applying the spirit-level to its surface in the direction X Z, tighten the screw V, and complete the adjustment with the screw T. Then applying the level to it in the direction of the pivots (and at right angles to X Z), tighten the screw I, and complete the adjustment with the screw J. Go through the two adjustments again, without loosening the screws V and I, making use of the screws T and J only.

"Having thus rendered the mirror quite horizontal, see if the line xii of the horary circle D is quite in juxtaposition with the line marked on the index E, and if it is not so, move the index and the circle D cautiously, so that these two lines become a prolongation one of the other, but without allowing the index E to touch the circle D, otherwise a displacement of this index might take place in turning the axis A. Now loosen the screws V and I.

"Find out from an astronomical almanack the declination of the sun on the day on which you are working, and, taking the mirror in the right hand at R, communicate to it such a motion as to very nearly bring the indicated degree of the circle P opposite the index. Tighten the screw V, and turn the screw T until the index exactly marks the declination of the sun at the time.

"Taking now the mirror in the hand at R, and noting on your watch the *true time*,* make the index indicate this time on the

* "The *true* or *apparent time* is the time marked by the sun-dial, and not the time marked by the ordinary clock, which is *mean time*. The difference between the mean time and the true time constitutes the *equation of time*.

"To set a heliostat well, a knowledge of the exact time (to within a

circle D, by communicating a rotatory motion to the axis A. When this is very nearly effected, let go the mirror and tighten the screw I. Then turn the entire instrument round on its pivot *a*—taking it by the screw B, and without stirring the table N—until you see the thread of solar rays emerging from the aperture of the sight Z, and falling on the centre of the sight X. Then tighten the screw *a*, and the heliostat is set.

"If now, in succession, you open the screw I, and close the screw H, you will see the image of the sun remain motionless for hours together at the centre of the sight X, and it is only when this is the case that the heliostat is accurately set. It must never be made use of until its working has been thus verified. When the heliostat is set, the table N and the pieces L M, K J, J M being left in position, all the other parts may be dismounted and taken away. To do this, open the nuts which hold the circles C and D; lower the clock-work; open the collar I, by removing the screws which close it round the axis; and open and remove the upper half of the bearing in which the upper part of the axis works. The mirror, the arm-rest, and the axis can then be removed, without the heliostat having to be re-set when they are replaced.

"There are three ways of setting up the heliostat in connection with other apparatus.

"1. The most simple consists in inclining the accessory apparatus so that its optical axis coincides with the axis of the heliostat.

"2. The second consists in rendering the reflected rays horizontal by means of a second mirror, and in any direction whatever.

"3. The third in rendering the reflected solar rays horizontal by a mirror inclined at 45° to the axis of the heliostat, in such a way as to reflect them from the east to the west, or from the west to the east."

The mutual adjustment of heliostat and apparatus employed is thus effected:—

Firstly, it is placed in a direction from south to north (the heliostat to the south), and in doing this the place of the sun at the true noon-time is the guide. Having levelled the heliostat, suspend a plumb-line in front of the combined apparatus, plunge its weight in a bucket of water to keep the line steady, and in such a position that the line stands but a short distance from the screw B of the heliostat. Having set a watch (as described in the previous foot-note) to the true time, at *the true noon time precisely*, move the entire instrument from left to right or from right to left, so that the shadow of the plumb-line divides the screw B, the circle D, the axis A, and the accessory apparatus into two exactly equal parts. The entire apparatus is then in adjustment if the image of the sun appears as a fixed spot.

minute) is indispensable, and should be carefully attended to. Throughout the United Kingdom, at all railway stations, Greenwich *mean* time is always adopted for civil convenience, although obviously that time does not truly indicate mean time in other localities situated east or west of Greenwich. In any place, therefore, where a heliostat is to be arranged for the day, it will be very easy to calculate the *true* or *apparent* time by the following data:—

"1. The exact longitude of the spot to within fifteen seconds must be accurately ascertained. This can easily be got from the Ordnance maps.

"2. Greenwich *mean* time must be known, and this, to within a few seconds, can be ascertained at the nearest railway station.

"3. An astronomical almanack (Dietrichsen and Hannay's is very convenient and cheap), containing the *equation of time, declination of the sun*, etc., for every day of the year, is required.

"With these data known, suppose it is wished to arrange a properly set-up heliostat at Liverpool for a day's work, say at nine o'clock on the 1st of October, 1867. The longitude of Liverpool is three degrees west of Greenwich; the *true* time at that place is, therefore, exactly twelve minutes later than London time. First ascertain accurately nine o'clock by Greenwich mean time, deduct from that twelve minutes for difference of west longitude, then turn to the almanack for the *equation of time* for that day, which happens to show *minus* ten minutes fourteen seconds. In other words, the sun is faster, or passes the meridian sooner than the mean time indicates. This difference must therefore be added to the *mean* in order to get the true time. Thus, 9 hrs. − 12 min. + 10 min. 14 sec. = 8 hrs. 58′ 14″, which is the time at which the horary circle of the heliostat is to be set for that day at Liverpool. And so for any other place, taking care, however, to note that a divergence from Greenwich time must be *added* when the place is east longitude, and that every 15′ of longitude is equivalent to one minute of time.

SEATS OF INDUSTRY.—XVI.

NOTTINGHAM.

BY WILLIAM WATT WEBSTER.

On the banks of the Leen, about three-quarters of a mile from its junction with the Trent, stands Nottingham, the capital of Nottinghamshire, the chief seat of the bobbin-net and lace manufactures of England, and one of the principal centres of the English hosiery trade. This important manufacturing town occupies a very picturesque and romantic position near the south-western extremity of what was formerly Sherwood Forest, the head-quarters of Robin Hood and his band, but is now a cultivated district. It is built partly at the foot and partly on the broken and occasionally steep declivities of a red sandstone rock, rising 133 feet above the level of the surrounding meadows, and overlooking the valley of the Trent. The origin of the town is hid in obscurity, but it is believed that the site it occupies was a favourite resort of the Druids, and that the numerous caverns and vaults with which the rock is perforated were hollowed out by them. The Saxons called the place *Snotenagaham* or *Snottingaham*, and from this word, which signifies a retreat in rocks, the name Nottingham was doubtless derived. During the Saxon Heptarchy Nottingham belonged to the kingdom of Mercia; and after the Heptarchy terminated in 828 A.D., it was a Danish borough. In the reign of Ethelred I. there was a fortress on the rock; and in the time of his successor, Alfred the Great, the town had become of sufficient importance to give its name to the county. Ancient records mention that the Danes received a check from the town of Nottingham, and that they were defeated by Alfred in a great battle fought in the neighbourhood. Nottingham was first walled in by Edward the Elder in the beginning of the tenth century; and at the time of the Norman Conquest, as appears from the Domesday Survey, it contained 120 dwelling-houses. William Peveril, the natural son of William the Conqueror, built a castle on the summit of the rock, for the purpose, it is understood, of overawing and repressing the outlaws, who sought shelter in the old forest.

Nottingham claims to be a borough by prescription, but it received charters from Henry II., and many subsequent monarchs. Edward I., in the year 1284, granted it the privilege of sending two members to Parliament; and Henry VI. constituted the town a county by itself. In the reign of Edward III.—"the greatest of the Plantagenets"—several Parliaments sat at Nottingham, in one of which laws relating to the settlement of Flemish artisans in England were passed. During the Wars of the Roses Nottingham was the principal rendezvous for the troops of Edward IV. and Richard III., and it was from this town that the latter marched to the fatal battle of Bosworth Field. Charles I. selected Nottingham as the spot where he formally erected his standard against the Parliament; but the inhabitants of the town being warmly attached to the Republican cause, he was soon after compelled to evacuate the town and castle, which fell into the possession of the Parliamentary forces. Being attacked by the Royalists at a later period, the castle, gallantly defended by Colonel Hutchinson, a native of Nottingham, successfully resisted a prolonged and determined siege; but when the civil war was over, it was dismantled by the Protector. Subsequently it was pulled down; and in 1674, William Cavendish, Duke of Newcastle, erected on the site a mansion resembling a castle only in size and name, which was destroyed by a body of rioters in a disturbance that took place in 1831, ostensibly as a protest against the rejection of the Reform Bill by the House of Lords. Of the ancient castle only a few vestiges remain.

The modern industrial history of Nottingham may be said to date from the invention and introduction of the stocking-frame, which was adopted at nearly the same time by the manufacturers of Nottingham and Leicester. The art of weaving stockings out of worsted, silk, and other materials, was discovered in Scotland, and it was improved upon in France and Spain, before it came to be generally practised in England. Previous to this the stockings worn were simply tight-fitting trouser-legs or gaiters, with feet attached to them. A passage in Stubbes's "Anatomy of Abuses," published in 1596, enables us to fix the date when the knitted stocking began to supplant the cloth one. "They have nether-stocks," says the author of this work, referring to the fops of the period, "not of cloth, though never so fine, for

that is thought too base, but of worsted, silk, thread, and such like, or else, at the least, of the finest yarn that can be got, and so curiously knit, with open seam down the leg, with quirks and clocks about the ankles, and sometimes haply interlaced about the ankles with gold or silver threads, as is wonderful to behold. And to such impudent insolency and shameful outrage is it now grown, that every one almost, though otherwise very poor, having scarce forty shillings wages by the year, will not stick to have two or three pair of these silk nether-stocks, or else of the finest yarn that may be got, though the price of them be twenty shillings or more, as commonly it is. The time hath been," adds this enemy of luxury and expense, "when one might have clothed all his body well, from top to toe, for less than a pair of these nether-stocks will cost."

But an improvement had already been effected in the method of making knitted stockings that was destined to reduce the cost of their production, and bring them into universal use. Ten years before Stubbes denounced the luxury of "nether-stocks," William Lee, a native of Woodburgh in Nottinghamshire, and a graduate of St. John's College, Cambridge, was appointed curate of Calverton, a parish near the place of his birth; and in 1589, this country clergyman had in operation a stocking-frame, consisting of a row of knitting-needles kept going by a treadle, which produced stockings far more quickly than they could be woven by hand. Lee's machine has, of course, been greatly improved upon; but all the machinery now in use for the manufacture of knitted hosiery is worked upon the same principle. In connection with this important invention two romantic stories are told, which although not properly authenticated, may nevertheless contain some portion of truth. According to one of these accounts, Lee, while a student, courted a pretty country lass, who made her livelihood by knitting stockings. Being annoyed at finding her so engrossed in her occupation as to be unable to attend to his love-making, Lee sought some means of simplifying her labours, and securing her more leisure to walk and talk with him—the stocking-frame being the result. The other story is still more romantic, but not less probable. It is said that, after leaving college, Lee forfeited his fellowship by marrying the stocking-knitter, and that after he entered on his curacy, the wife found it necessary to continue her knitting in order to eke out the small stipend her husband received. Finding his wife toiling at the knitting-needles early and late, Lee was led to think over the process, and eventually discovered the principle of the stocking-frame with which his name is associated. The first machine invented by Lee was only suitable for knitting worsted, and it was not till 1598 that he succeeded in producing a frame delicate enough to make silk stockings. Although Lee's career as a stocking manufacturer hardly comes within the scope of this paper, it may be mentioned that about the year 1591 he threw up his curacy, carried his machine to London, and devoted himself wholly to its improvement, and to efforts to bring his invention into favour. Through the intercession of Lord Hunsdon, Queen Elizabeth was induced to visit the poor parson in Bunhill Fields, who had invented a wonderful contrivance for knitting stockings; but, while admiring the ingenuity of the machine, she refused to grant him a patent for his invention. In reply to a request for assistance from Lee's patron, Lord Hunsdon, Her Majesty is reported to have said, "I have too much love for my poor people who obtain their bread by the employment of knitting, to give my money to forward an invention that will tend to their ruin, by depriving them of employment, and thus make them beggars. Had Mr. Lee made a machine that would have made *silk* stockings, I should, I think, have been somewhat justified in granting him a patent for that monopoly, which would have affected only a small number of my subjects; but to enjoy the exclusive privilege of making stockings for the whole of my subjects, is too important to be granted to any individual." Lee carried on stocking manufacture for seven or eight years in Bunhill Fields, and had at one time nine machines in operation; but the expenses he incurred in perfecting his invention were greater than the profits he derived from the production of his frames, and he fell into such poverty and dejection, that he was almost induced to abandon the undertaking. In 1605, however, he went to France, on the invitation of Henri Quatre, and set up his machinery at Rouen; but after the assassination of his royal patron and protector, he wandered about from place to place, persecuted as an Englishman and a Protestant, and probably also as an inventor, until partly, if not wholly, through starvation and a broken heart, he died at Paris in 1610, just as his invention was coming to be generally accepted. Seven of his workmen in France returned to Nottingham, and entered the service of Aston, one of Lee's apprentices, who effected some improvements on his master's machine, and under Aston's management they laid the foundation of the stocking manufacture of England. In the time of the Commonwealth the stocking trade was so extensive, that the London stocking weavers sought to be incorporated in a guild, but it was not till 1663 that their wish was granted by Charles II. By the year 1670 there were 700 stocking-frames in operation in England; and in 1753 their number had risen to 14,000. In 1845 there were about 73,000 persons employed in the manufacture of stockings in Great Britain, and the quantity produced was reckoned to amount to upwards of 3,500,000 dozen pairs. At the present time it is estimated that nearly four-fifths of the stockings worn in the world are made in this country; and Nottinghamshire, and the adjoining counties of Leicester and Derby, are the districts where this trade is principally carried on.

The manufacture of a description of lace called bobbin-net has contributed to the prosperity of Nottingham in an almost equal degree with the stocking trade. The first attempts to manufacture lace by machinery were made as early as 1768; but although frequent efforts were subsequently made to shorten the tedious process of making lace on the pillow, no very great success was achieved till Mr. Heathcoat of Tiverton, in 1809, discovered and obtained a patent for his invention of the bobbin-net frame. Seven years later steam-power was first applied to this machine, and by 1822 or 1823 bobbin-net frames were generally driven by steam-engines. About the latter date the trade also received a great stimulus through the expiry of Heathcoat's patent. The quantity of bobbin-net lace produced increased enormously; the prices fell in consequence; and in a short time Nottingham lace to a great degree supplanted the pillow lace for which Flanders, France, and certain English counties were once highly celebrated. In the manufacture of plain nets Nottingham soon rivalled and surpassed all competitors; and the produce of the Nottingham bobbin-net frames was smuggled into those very countries from which lace had formerly been smuggled into England. In the early years of the trade plain nets alone were made, but after a time quillings were introduced, and at a later period figured or fancy patterns were produced. Quillings and figured patterns are the highest priced products of the bobbin-net frame, and these are the principal descriptions of lace goods manufactured in Nottingham. To show the rapid progress made in this industry, we may quote the account that Mr. Felkin gives of the trade in 1835, in his "History of the Machine-wrought Hosiery and Lace Manufactures." "In 1835," says the author of this standard work, "there were used in this apparently minute branch of industry, 1,850,000 lbs. of Sea Island cotton wool, valued at £185,000, and 25,000 lbs. of silk, valued at £40,000." The value of the produce of these raw materials and their disposal are stated to have been as follows:—"Home consumption for nets, £320,000; for quillings, £210,000; for fancies, £580,000—total, £1,110,000. Foreign trade, in nets, £340,000; in quillings, £282,000; in fancies, 480,000—total, £1,102,000. In the same year the plain nets sent from other parts of the kingdom to Nottingham to receive the finishing operations of gassing, bleaching, and dressing, were estimated at £328,000." A few years ago it was calculated that there were about 1,800 bobbin-net and warp-lace frames in operation in the town and neighbourhood of Nottingham.

In the early part of the present century Nottingham gained an unenviable notoriety in consequence of the frequency and violence of the riots that took place there. Among the most memorable of these were the riots of the Luddites, which were continued at intervals through a period of years. In 1811 great distress prevailed among the weavers of England, owing principally to the slackness of trade occasioned by the exclusion of British goods from foreign markets. The operatives, however, attributed their misery wholly to the spread of machinery; and combinations for the purpose of destroying the bobbin-net and stocking frames, which they supposed had deprived them of employment, were frequent in Nottingham. These riots were so well planned, and so destructive, and the rioters were so suc-

cessful in escaping the vigilance of the police, that Parliament was eventually compelled to adopt special and very stringent measures for their suppression. An act declaring the wilful and malicious breaking of a stocking or lace frame to be a capital offence had to be passed before the Nottingham operatives abandoned their attempts to check the application of machinery to these manufactures by violent means. Many minor disturbances broke out in Nottingham between the Luddite riots and the outbreak to which we have already referred. These riots injured the trade of the town.

Nottingham enjoys considerable natural facilities and advantages for the successful prosecution of its manufactures and commerce. Coal is found in abundance at a distance of about two miles from the town; and there is a canal connecting the town northwards with the Codnor iron and coal district, and southwards with the Trent and the canal system of the northern midland counties. It need hardly be said that its railway communication is almost perfect. The Trent is navigable up to the point opposite Nottingham, and is there crossed by an ancient bridge, consisting of nineteen arches, and also by railway bridges. On the whole the town is but indifferently built, a large proportion of the streets being narrow and irregular, and in the older quarters of the town houses are to be found standing back to back without any interval between them. The houses for the most part are constructed of brick, and many of the streets rise above each other in successive terraces. One very crowded quarter, called the Marsh, lies about seventy feet below the prison, which is built on the edge of a rock. Extensive improvements have, however, been made in Nottingham during the past twenty years, many new streets having been constructed, and villas built in all directions. Formerly the burgess land formed a belt round the town of about a thousand acres, but this land was enclosed under the General Enclosure Act some twenty years ago, and since that time part of it has been built upon and part reserved for pleasure grounds, promenades, etc., eighteen acres of it being formed into an arboretum, to which the inhabitants have free access on three days of the week. The people of Nottingham also enjoy the use of a park of about 130 acres, belonging to the Duke of Newcastle. A striking contrast to the narrow streets of the town is afforded by the spacious market-place, which is a triangular area of five acres and a half, surrounded by lofty houses and shops with arcades. None of the public buildings of Nottingham possess any marked feature of interest or any remarkable history, except perhaps St. Mary's Church, an ancient Gothic structure, supposed to have been originally erected in the seventh century, but which has since been defaced by incongruous alterations in the Doric style. Among the institutions of the town may be mentioned the Free Grammar School, which was founded in 1513, but fell into disuse before the close of the last century, and was re-established and revived in 1807; the Blue Coat School, which clothes and educates sixty boys and twenty girls; the People's College, founded by subscription in 1846, to afford superior instruction to the working classes; and a National and a Lancastrian School.

In addition to the staple manufactures of Nottingham already mentioned, the town contains cotton, worsted, and silk mills; extensive establishments for the construction of bobbinnet and stocking-frame machinery; and large bleach-fields, malt-houses, and breweries. To illustrate the rapidity of the growth of Nottingham during the present century, the population returns may be cited. There were in Nottingham in 1801, 28,861 inhabitants; in 1811, 34,253; in 1821, 40,415; in 1831, 50,680; in 1851, 57,407; in 1861, 74,693; and in 1871, 86,608.

PRINCIPLES OF DESIGN.—XIX.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS (*continued*).

PURSUING our consideration of floor coverings, we may notice that a number of beautiful Indian carpets, such as we referred to in the last article, may be seen at the museum in the building of the new India Office at Whitehall, which museum is open free to the public (Figs. 66, 67, 68). Some good examples have been shown at the International Exhibitions at South Kensington, and at other exhibitions throughout the kingdom. As to the nature of the pattern which may be applied to a carpet, we have "all-over" patterns, or patterns spreading regularly all over the surface; "geometrical" patterns, or those which have an apparent regularity of structure; and panel patterns, or those in which particular parts are, as it were, framed off from other parts.

First, as to "all-over" patterns. These are what we almost always find in both Indian and Persian carpets, and are, undoubtedly, the true form of decoration for a woven floor covering. What is desirable is an evenly spread pattern, such as will give richness without destroying the unity of the entire effect. The pattern may have parts slightly accentuated or emphasised beyond other parts, but not strongly so, and this emphasising of parts must be arranged with the view of securing to the pattern special interest. Thus, if a carpet is viewed at a distance it should not appear as devoid of all pattern, but through the

Fig. 67.

slight predominance of certain leading features (in Indian carpets, generally of ornamental flowers) the plan of the design should be indicated. More detail should be apparent when the work is seen from a nearer point of view, and still more upon close inspection; but in no case should any parts appear strongly pronounced, or otherwise than refined and beautiful, and in no case should there be a want of interest manifested by the pattern.

Carpet patterns are generally better if founded on a geometrical plan. In this way most of the Indian and Persian patterns are constructed. A geometrical plan secures to the design a manifestation of order and thought in its formation. Panel patterns, unless very carefully managed, become coarse. In some Indian carpets we find a sort of panel in which the colour of the ground is changed from that of the general ground of the carpet, but here the panel has usually a truly ornamental form, and is, indeed, rather a large ornament than a sort of frame enclosing a distinct space. Whenever a panel occurs in an Indian, Persian, or Moorish carpet, it is so managed, and its surroundings are such, as to cause it to appear as a part natural to the general design; but it is far otherwise with the panel patterns which we occasionally see in our shop-windows as the produce of native industry, and it is far otherwise with those which are

used in vast quantities by the Americans. Judging from the carpets which they order, I imagine that nowhere on earth is taste in matters of decorative art so depraved as it is in America. It is true that the great floral patterns have ceased to be demanded by them, but they are only replaced by coarse, raw-looking, panel patterns, coloured in the most vulgar manner, and without even a hint at refinement or harmony of colour. Let the pattern be "loud" and inharmoniously coloured, and the chances of its sale in the American market are great.

Fig. 68.

But we must not forget that even in our own country bad patterns sell equally as well as good, inartistic patterns as well as those which are of a more refined character, and that even here in Great Britain more of the indifferent, if not of the very bad, sells than of the good. Let us cast the beam, then, from our own eye, before we try to extract it from that of another.

The ground colour of a carpet may vary much, as we all know; it may be black, blue, red, green, or white. If the ground of a carpet is pure white, it is almost impossible that it will look well. When I make this assertion I am often told that some of the Indian carpets which I so much admire have white grounds. This is a mistake. Some of them have light grounds, but not white grounds. They have light cream-grey grounds, or green-white grounds, but not pure white, and this tone of the ground altogether alters the case. Yet even with a light-toned ground it is not an easy matter to make a carpet which shall appear as a suitable background to the furniture of a room; it can be done, but it is a thing difficult to achieve. The safest and best ground for a carpet is black or indigo blue. If on this ground a closely fitting, well-studied pattern be arranged, drawn in small masses of bright colour, a beautiful bloomy effect may be achieved, and a glance at our best shop-windows will show that the most satisfactory carpets are coloured in this way.

Fig. 66.

As to the size of the pattern we can say but little, as this will be determined by the coarseness or fineness of the fabric. In a Brussels carpet each stick is about the one-tenth of an inch square. In some Turkey carpets each stick is a quarter of an inch square. It is obvious that a much smaller and finer pattern can be produced in Brussels than in Turkey carpet.

A carpet pattern is best small, or at least small in detail if not in the extent of the design. A pattern may repeat three or four times in the width of the fabric (twenty-seven inches if Brussels), or but one figure may be shown, yet in this latter case the detail of the pattern may be as great as in the former. That degree of smallness which is compatible with tolerable distinctness of detail is desirable. For this reason Turkey carpets are not altogether satisfactory; no fine pattern can be worked in them, and besides this they have no colour-bloom and little colour-harmony. In some respects they are good, but altogether they are not satisfying.

Before I close these remarks upon carpets, let me say that, as designers, manufacturers, and consumers, we are one and all timid of new things. We want daring—the energy to produce new things, to manufacture them, to use them. What if the pattern is "extreme," if it is better than others? what if Mrs. Gamp should think us eccentric?—better be eccentric than ever harping on the same string. If we could but bear calmly the derisive smiles of the ignorant, art-progress would be easy.

With us carpets cover the entire floor. In London these carpets are nailed to the boards, and but seldom taken up. In some parts of England we find rings sewn around the under edge of the carpet, which rings are looped to the heads of nails. Carpets so furnished can be more readily removed for cleaning than ours, which are nailed to the floor. Square carpets, such as the Turkey, Indian, and Persian, are spread loosely on the boards, and can be taken up and shaken without difficulty. This is unquestionably the healthy plan of using a carpet, and it is also an artistic plan. If the outer portion of the room floor is formed of inlaid wood of simple and suitable pattern, and a large loose square carpet is spread in the centre, we have an artistic effect, and the desirable knowledge that cleanliness is also attainable with a reasonable expenditure of labour.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XVI.—THOMAS BEWICK, ENGRAVER.

BY JAMES GRANT.

THOMAS BEWICK, the reviver of the most useful art of wood-engraving in England, was born on the 11th of August, 1753, at Cherry-burn, about twelve miles westward from Newcastle, where his father rented a small land-sale colliery at Mick-lay-bank, near his residence, and in the pit whereof the future engraver worked in the coal seams when a boy. After a time, he was sent as a day-scholar to a school kept by the Rev. Mr. Gregson, at Ovingham, and as the parsonage in which his preceptor lived is prettily situated on a bank sloping downward to the Tyne, its locality seems early to have found pictorial interest in young Bewick's eye, as many reminiscences of it are to be found in his woodcuts, the gate being introduced with little variation in four different subjects; while in his tail-pieces are many other local memories of a similar kind.

English reading, writing, arithmetic, and a smattering of Latin, however, were all the acquirements the limited means of Bewick's father could procure him. Having early shown a decided taste for drawing, he was apprenticed by his father to Mr. Ralph Beilby, an engraver, living in Newcastle. This was on the 1st of October, 1767, and he was bound for a term of seven years; but it must be borne in mind that Beilby was not a wood-engraver, and his business in the copper-plate line allowed but little scope for artistic display. He engraved a few plates for obscure local books, when such chances came in his way; but his chief work lay in executing brass plates for doors, with the owners' names filled in with black sealing-wax, after the manner of the old *niellos*, so called from an old species of ornamental engraving resembling damask work; but of the art of wood-engraving, though long practised on the Continent, little or nothing was then known in England—at least, very little and humble were the efforts in that way. Types cut in wood were introduced at Strasburg by Guttenburg, so early as 1442; and in 1496, Wilhelm Pluydenwurff and Michael Wolgemuth, the first actual wood-engravers whose names are known, furnished in that year the folio plates for the Nuremburg Chronicle, containing figure subjects and views of towns. During the seventeenth century a few foreign engravers visited and worked in England, the most eminent being Crispin de Passe, Hollar, Dorigny, and others; but until the time of Faithorne the elder in 1670, our native engravers limited themselves to the production of maps and portraits, all of which were below even mediocrity. John Payne, an Englishman, first aspired to other cuts, and executed landscapes, flowers, and animals, etc., his chief print being the *Royal Sovereign*, man-of-war. Then followed the Whites, father and son, George Virtue (born 1684, died 1756), Woollet, Brown, Sir Robert Strange, and a few others.

Bewick's attention to the great value of wood-engraving was first drawn in consequence of his master having been employed by Dr. Charles Hutton, then a schoolmaster in Newcastle, to cut on wood the diagrams for his "Treatise on Mensuration," the printing of which was commenced in 1768, and took two years to complete. The cutting of these diagrams was committed by Mr. Beilby to young Bewick, who invented a graver with a fine groove at the point, thus enabling him to cut the outlines by a single operation. Ninepence per week was the sum then paid by young Bewick for his humble lodging in Newcastle, and weekly his mother sent him a large brown loaf, baked by herself in their home at Cherry-burn, whither he returned in October, 1774, on the expiration of his apprenticeship, but he still continued to work for Mr. Beilby.

Intending to apply himself now exclusively to the art and study of wood-engraving, he drew and executed several cuts as specimens of his power, and in 1775 he received a premium from the Society for the Encouragement of Arts and Manufactures, for a cut of the "Huntsman and the Old Hound," an oval print with a flowered border; and a fac-simile of this cut was used in the first collected edition of "Gay's Fables," printed at Newcastle by T. Saint in 1770.

Six years later found him making a tour, staff in hand, with a knapsack on his back, among the Cumberland lakes, when on a visit to some of his relations; and long after, in other days, he used to speak with admiration of the border mountain scenery, and "of the beauty of the white-washed and slate-covered cottages on the banks of some of those lakes." In a tail-piece to the first volume of his "British Birds," he introduces a sketch of himself, as he appeared on this tour, in his travelling costume, drinking from a wayside runnel out of the flap of his hat. After a brief visit to London, he became a partner with his old master, Beilby of Newcastle. He disliked the bustle of the metropolis, which he stigmatised as "a vast province covered with houses," and even advised his pupils to remain, when they could do so, in the country, and enjoy there the fresh air, the beauties of Nature, and of all things contentment.

"I am still of the same mind that I was when in London," he once wrote to his old schoolfellow Christopher Gregson, son of his former preceptor; "and that is, I would rather be herding sheep on Mick-lay-bank top than remain in London, though for doing so I was to be made the Premier of England!"

Bewick loved to spend all his hours of recreation in the open air, on his native Northumbrian hills, studying the characteristics of birds and beasts in their natural state, and noting those picturesque details of rural life which formed sketches and tail-pieces to his works. On the partnership with Beilby being fairly arranged, Bewick took as apprentice his younger brother John, who had been born in 1760; and though he assisted his partner in all the more mechanical parts of their business, he applied himself, whenever he could do so, exclusively to the art of wood-engraving. In addition to the cuts for "Gay's Fables" in 1779, he published an edition of "Select Fables," 1784, both printed by Saint; and in the latter he was assisted by his brother, as the title-page of the new octavo edition published at Newcastle, in 1820, bears "Select Fables, with cuts designed and engraved by Thomas and John Bewick and others, with a memoir and catalogue of their works."

In this work the animals are better drawn, the sketches more free, the backgrounds more natural, and the foliage fuller than in those for "Gay," showing that he improved as his art was exercised. "In the best cuts of the time of Dürer and Holbein, the foliage is generally neglected; the artists of that period merely gave general forms to trees, without ever attending to that which contributes so much to their beauty. The merit of introducing this great improvement into wood-engraving, and of depicting quadrupeds and birds in their natural forms and with their characteristic expression, is undoubtedly due to Bewick."

Nine shillings each was the sum Bewick received for the cuts in the "Select Fables!" He was for five years engaged on his "General History of Quadrupeds," which was begun in 1785, and was published in 1790 by Robinson, Paternoster Row, in octavo, and the title-page announces the "figures engraved on wood by T. Bewick." His own account of the origin of this work may be quoted here:—

"From my first reading, when a boy at school, a sixpenny History of 'Birds and Beasts,' and then a wretched composition called the 'History of Three Hundred Animals,' to the time I became acquainted with works of natural history written for the perusal of men, I was never without the design of attempting something of this kind myself; but my principal object was, and still is, directed to the mental pleasure and improvement of youth; to engage their attention, to direct their steps aright, and to lead them on till they became enamoured of this innocent and delightful pursuit. Some time after my partnership with Mr. Beilby commenced, I communicated my wishes to him, and after many conversations he came into my plan of publishing a History of Quadrupeds, and I then immediately began to draw the animals, to design the vignettes, and to cut them on wood; and this, to avoid interruption, frequently till very late in the night; my partner at the same time undertaking to compile and draw up the descriptions and history at his leisure hours, and in evenings at home. With the accounts of the foreign animals I did not much interfere; the sources whence I had drawn the little knowledge I possessed were open to my coadjutor, and he used them; but to those of the animals of our own country I lent a helping hand. This help was given in daily conversations, and in occasional notes and memoranda which were used in their proper places."

Of this work a second edition appeared in 1791, and a third in the following year at Newcastle. Some of the illustrations displayed a humour said by certain critics to be worthy of Hogarth, and as a specimen of this, one representing a sour-visaged old fellow in a three-cocked hat, conveying bags of corn

to a mill on a lean, starved, over-laden, broken-kneed, and evidently string-halted horse, which he is beating with a stick, has been prominently selected. A hungry-looking dog goes in front towards a fence, beyond which, in distance, appears a farm gate and a square gallows, a feature frequently introduced by Bewick in sketches illustrative of knavery, malice, or cruelty.

Another sketch, as indicative of pathos, was selected by them—the "Ruined Cottage and Sheep." Near a hovel, of the roof of which three couple-poles, some thatch, and a chimney alone survive, "while all around is covered with snow, a lean and hungry ewe is seen nibbling at an old broom, while her young and weakly lamb is sucking her milkless teats. Such a picture of animal want, conceived with so much feeling and so well expressed, has, perhaps, never been represented by any artist except Bewick."

Thus each of his illustrations was made, by its graphic power, to tell a story; and the success attending his work on Quadrupeds induced him to commence at once the designs and woodcuts for a "History of British Birds," the first volume of which was published in 1797; the simple, clear, and correct letterpress being, as in the former work, the production of his partner Mr. Beilby, with whom his partnership was dissolved in that year; hence the literary portions of the second volume, which appeared in 1804, were written by Bewick himself, but revised for the press by his friend, the Rev. Henry Cotes, Vicar of Bedlington, in the county of Durham.

The woodcuts of this work established, more than any of its predecessors, the fame of Bewick as a wood-engraver, and moreover as an artist; and nothing that has been produced since can be compared to them, nor shall they be equalled, says a writer, "till a designer and engraver shall arise, possessed of Bewick's knowledge of nature, and endowed with his happy talent for expressing it." He attained a skilful management of light and shade, which it is almost impossible to produce by means of copper-plate engraving.

An edition of his Quadrupeds appeared in two volumes in 1809, another in 1811; in 1818, he illustrated an octavo edition of "Æsop's Fables," with designs on wood, also published at Newcastle; and in 1821 appeared "A Supplement to the History of British Birds," in two parts, 8vo, at Newcastle.

Thomas Bewick diligently cultivated his inborn talents, and trusted neither to designers nor publishers for employment. He struck out a path and found employment for himself, seeking neither the directions nor the patronage of others; he thus preserved his independence, and was able to realise a competence together with no small share of worldly fame. Though his works were successful, he was never inattentive to self, and he frugally husbanded his earnings with an eye to provision in his old age.

In 1803, a portrait was painted of him by an artist named Murphy; but this he seems not to have had the vanity to engrave. On the 18th of April in that year, he gave the artist a letter of introduction to Mr. Christopher Gregson, the son of his old tutor before mentioned, then in London, and in this letter he pleasantly alludes to his own alleged beauty long ago when a boy.

"I do not imagine, my dear friend, that at your time of life you will be solicitous about forming new acquaintanceships; but it may not, perhaps, be putting you much out of the way to show any little civilities to Mr. Murphy during his stay in London. He has, on his own account, taken my portrait, and I dare say will be desirous to show you it on the first opportunity; when you see it, you will no doubt conclude that T. B. is turning bonnier and bonnier in his old days; but, indeed, you cannot help knowing this, and also that there were great indications of its turning out so long since."

When health began to decline, and he lost much of his old energy of mind, the summer of 1828 found him again in London. He was then in his seventy-fifth year, and nothing that he saw could interest him; he longed for his native Tyne and the scenery of Northumberland. Even the objects in which he felt the greatest pleasure once were void of that for him now; hence, when one of his oldest and most valued friends drove him to the Regent's Park, he was either too feeble or too careless—at all events, he declined—to alight and to visit the animals in the Zoological Gardens.

On his return to Newcastle, somewhat of his former health, spirit, and tastes returned to him, but for a brief space only, and on the Saturday before his demise he took the block of "The Old Horse waiting for Death" to the printers, that he might have a proof of it struck off for him. On Monday after he fell ill, and when the proof came he had ceased to exist, closing his long and useful life at his house on Windmill Hill, at Gateshead above the Tyne, on the 8th of November, 1828. He was interred in the churchyard of Ovingham, of the parsonage of which he has left one of his most charming little woodcuts.

PRACTICAL PERSPECTIVE.—XIV.

In this lesson another study of polygons is given.

Fig. 69 is the plan of an octagonal plinth, on which rests an octagonal prism, of which the smaller figure is the plan.

The octagon is enclosed in a square, A B C D, and this is to be first projected as shown in previous lessons.

Proceeding then to Fig. 70, mark the points E and F between A and B, and lines drawn from them to the centre of the picture will cut the back line of the square in I and J.

Similarly, the points K and L being marked on the picture-line between A and C, and lines drawn from them to the point of distance will give the points K′ and L′ in the perspective side of the square, and from these horizontal lines across the figure will give the points G and H.

Join E F, F G, G H, H I, I J, J K′, K′ L′, and L′E, and the plan of the octagon will be completed.

Now raise perpendiculars from each of the angles of the square; mark on either of the front ones A or B, the true height of the plinth, and complete the upper surface of the square block *a b c d*.

From each of the angles of the octagon raise perpendiculars, cutting the upper square in the points *e*, *f*, *g*, *h*, *i*, *j*, *k*, and *l*.

Join these points, and thus complete the upper surface of the octagonal plinth.

The plan of the octagonal block might, of course, have been projected inside the original perspective plan; but it is advisable, for the sake of clearness, to defer it until this stage, so that it may be projected at once on the surface on which it is required.

To do this, produce the edge of the upper surface to C, equal to the distant side of the square. Between *a* and C set off *a* O and C P, corresponding with A T and C S in Fig. 69; from these points draw lines to the point of distance; and from the points where these lines cut the line drawn from A to C, draw horizontals.

Between *a* and *b* set off M and N, and from these points draw lines to the centre of the picture; these, cutting the two horizontals last drawn, will give the perspective view of the square in which the minor octagon is contained.

Between M and N set off U V, the width of the side of the smaller octagon; and these, cutting the front and back line of the inner square, will give the two sides *u v*, *y z*.

Now between *a* and C set off *a* W and C X, corresponding with A W′ and C X′ in Fig. 69, and draw lines to the point of distance, cutting *a c*; from these intersections draw horizontal lines, which, cutting M R in *w x*, will give another side of the octagon, the corresponding side to which will be obtained by drawing horizontals from *w* and *x* to cut N Q in *w′ x′*.

Join *v w′*, *w′ x′*, *x′ y*, and *z x*, *x w*, *w u*, and the smaller octagon will be completed.

Now, to project the top of the prism, at the required height draw the line A′ B′, corresponding with the side of the containing square, and on it set off the widths M′, N′, U′, V′ precisely over the points similarly lettered on the line *a b* below.

From M′, N′, U′, V′ draw lines to the centre of the picture, and from *u*, *v*, *w*, *w′*, *x*, *x′*, *y*, and *z* draw perpendiculars to meet these. The points for the upper surface of the octagonal block will be thus obtained.

Exercise 66.

Put this object into perspective when standing at any distance (at pleasure) within the picture.

Exercise 67.

Scale ½ inch to the foot. Height of spectator, 6 feet; distance, 15 feet.

Subject, a hexagonal block of 3 feet side and 2 feet high, on which rests another hexagonal block, the side of which is 2 feet and the height of which is 8 feet.

Put this object into perspective when placed at 4 feet on the left of the spectator, the front of the lower block being on the picture-line.

Exercise 68.

Put the same object into perspective when another hexagonal block or slab rests on the top of it, precisely equal in size to the plinth on which the second block stands, but only half the height.

Give a perspective view of this tube when lying at 4 feet on the left of the spectator, its end being at right angles to the picture-plane.

Exercise 71.

Put this same object into perspective when lying at 3 feet on the right of the spectator, and 8 feet within the picture.

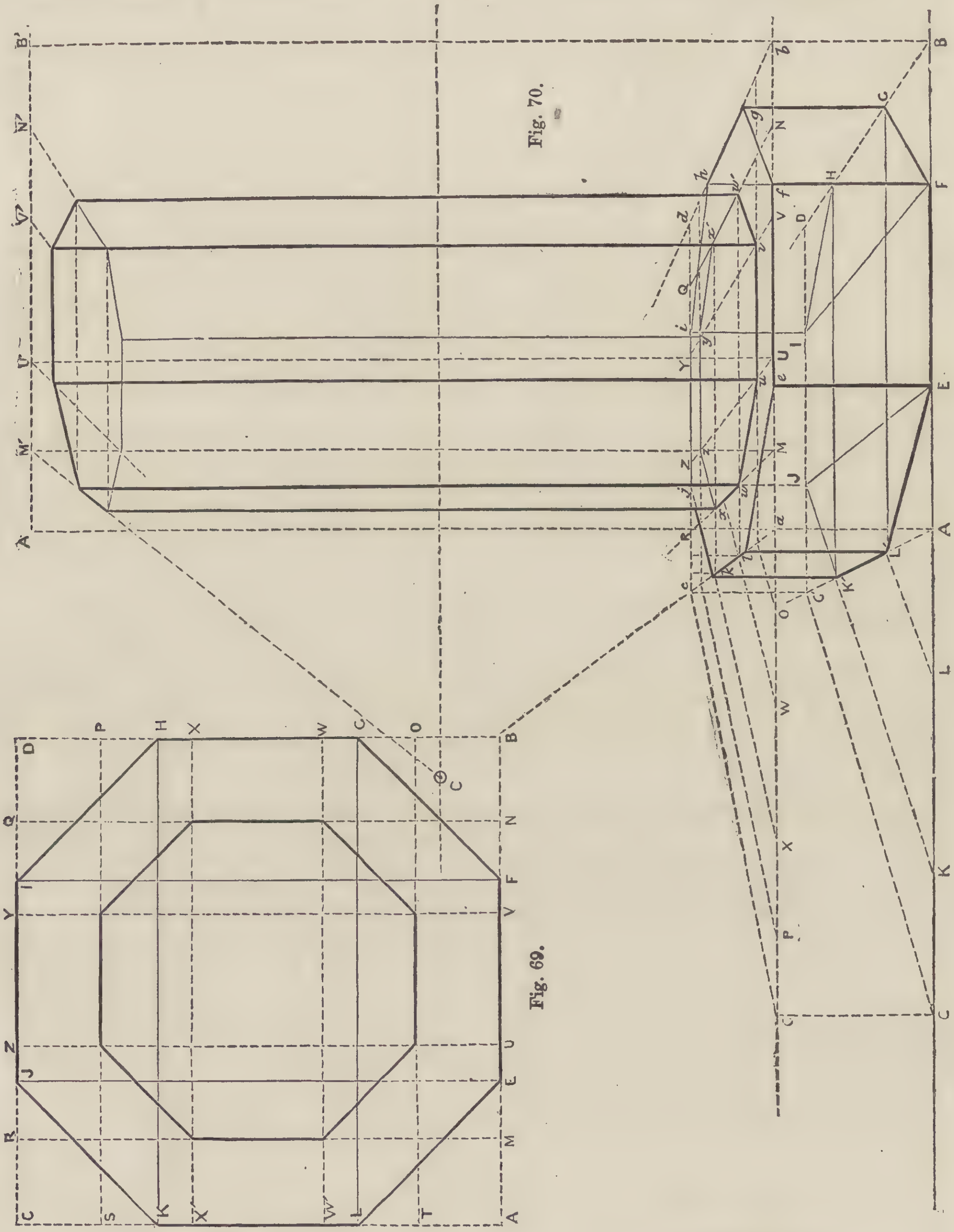


Fig. 70.

Fig. 69.

Exercise 69.

Put the same object into perspective when standing at 5 feet on the right of the spectator, at 6 feet within the picture.

Exercise 70.

Scale ½ inch to the foot. Height of spectator, 6 feet; distance, 15 feet.

Subject, an octagonal tube; side, 2 feet; length, 6 feet; thickness of material of which the tube is made, 6 inches (by scale).

Exercise 72.

Put the same tube into perspective when its octagonal end is vertical, and at 50° to the picture-plane, the nearest angle of the containing figure being on the picture-line at 3 feet on the left of the spectator.

Exercise 73.

Give a perspective view of this object when the long edges are at 30° to the picture-plane, and when it is situated at 5 feet on the right of the spectator, and 10 feet within the picture.

THE PERSPECTIVE OF CIRCLES.

To put circles and other curved forms into perspective, it is necessary that they should first be enclosed in the nearest rectilinear form which will contain them. In the case of circles this containing form will of course be a square.

Now let Fig. 71 be the circle which we require to put into perspective. Describe about it the square A B D C, and put the same into perspective at A (Fig. 72).

(It will be seen that the length of the side A B is not contained in this figure, nor is the point of distance. The student will, however, understand this elementary process.)

Now draw in Fig. 71 the two diameters E F and G H at right angles to each other, and project these in Fig. 72.

Draw the diagonals A D and B C, and insert these also in Fig. 72.

Now these diagonals cut the circle in the points M, O, N, P.

Through these points draw the lines I J, K L.

On the perpendicular A C in Fig. 72 mark off the heights I, K, and draw lines to the centre of the picture. These will cut the diagonals in the points M, O, N, P.

The perspective representation of the circle must now be traced by hand through the points E, M, H, O, F, P, G, N, E.

In the present study the circle is supposed to be the end of a cylinder, the length of which is represented by the distance from A to *a*.

At *a*, therefore, put the square into perspective, and draw the diameters *e f*, *g h*, and diagonals. Then horizontal lines drawn

Fig. 71.

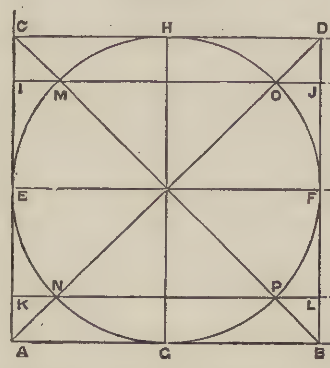
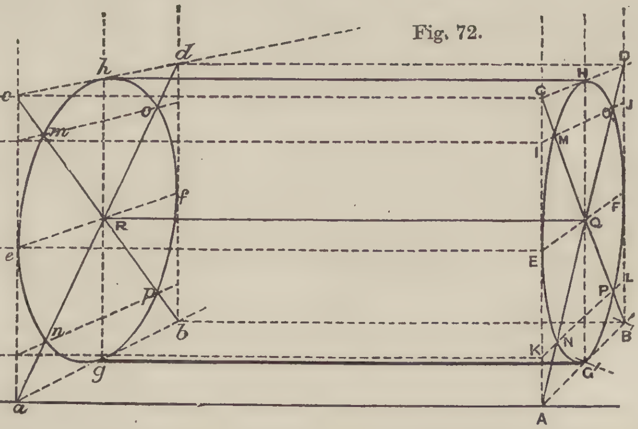


Fig. 72.



from the points M, N, O, P will cut the diagonals in the points *m*, *n*, *o*, *p*, and thus all the corresponding points will be obtained through which the curve is to be drawn.

The two ends are then to be united by the lines H *h* and G′ *g*. (The line Q R is called the axis, and this cylinder is spoken of as "having its axis parallel to the picture-plane.")

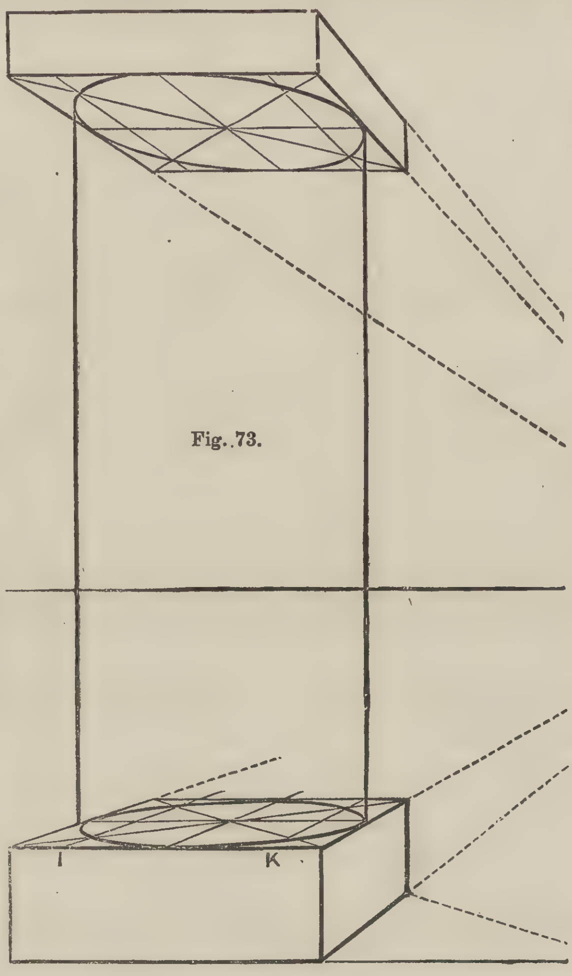


Fig. 73.

Fig. 73—This study is another application of the lesson given in Figs. 71 and 72, and represents a cylindrical column standing on a square base, and surmounted by a square slab.

Here the lower and upper blocks are completed first, and then the diameters and diagonals are drawn on the upper surface of the one and the under surface of the other.

The points I and K are measured from Fig. 71, the circle being the same size. From these points lines are drawn to the centre of the picture, and the necessary intersections obtained through which the curves are to be drawn, and these are afterwards united by vertical lines.

EXERCISE 74.

Put into perspective a cylinder when its axis is parallel to the picture-plane, its circular end at 4 feet on the right of the spectator, the object being placed at 8 feet within the picture.

The scale is $\frac{1}{2}$ inch to the foot, the height of the spectator is 6 feet, and the distance 15 feet. The diameter of the cylinder is 5 feet, and its length 6 feet.

EXERCISE 75.

Put the same cylinder into perspective when its axis is at 60° to the picture-plane, the object being situated in the immediate foreground, at 2 feet on the left of the spectator.

EXERCISE 76.

There is a row (four) of columns similar to that shown in Fig. 73. The following are the dimensions:—Width of plinth, 4 feet; height, 4 feet; width of upper slab, 4 feet; height, 6 inches; diameter of column, 4 feet; height, 12 feet. The distance between the columns is 8 feet. The scale is $\frac{1}{2}$ inch to the foot. Height of spectator, 6 feet; distance, 18 feet.

Put into perspective two rows of columns as above, the one at 8 feet on the left, and the other 4 feet on the right of the spectator, both rows to recede at right angles to the plane of the picture.

EXERCISE 77.

Put into perspective the column shown in Fig. 73, when the sides of the base are at 40° and 50° to the plane of the picture, the rest of the conditions at pleasure.

SANITARY ENGINEERING.—VII.

COOKING BY GAS.

In continuation of our series of papers on gas manufacture, and the various means of its application and consumption, with a view to economy and otherwise, we now come to cooking by gas, a process we venture to think not generally understood, but none the less worthy of the serious attention of all classes of the community. Its great recommendation is economy and the absence of waste. When a kettle has to be boiled, or a chop to be cooked in the ordinary way, the fire has to be lighted, and to burn up to a certain point of heat before the kettle can be put on to boil, or the fire is sufficiently clear for the chop to be cooked; and here is at once a large element of waste, as the fuel consumed in getting the requisite amount of heat developed for the purpose required is all so much loss. When gas is used in cooking the case is different: the gas has only to be turned on and lighted—there is no fire to burn up; the requisite cooking temperature is immediately available—time and money, as we venture to think we can show in the sequel, are both saved.

Perhaps the simplest thing that has to be done in the way of cooking is the boiling of a kettle; and about the heaviest daily undertaking of a cooking nature the providing of the daily dinner of an immense asylum, containing about 1,000 inmates. We shall endeavour, as far as our limits will allow, to give as definite an idea as we can of how these very different results can be economically and satisfactorily carried out by gas, and gas alone. To begin at the beginning. It has been ascertained by repeated experiments, into the detail of which our space does not allow us to go, that the most economical method of burning gas for cooking purposes is with a certain large admixture of atmospheric air, about 30 per cent., or perhaps a trifle more. *Light*, of course, the purpose for which gas is ordinarily used, is in this case of no account, the object being to develop the greatest amount of heat from the smallest consumption of gas, and the process is as follows. A No. 3 fish-tail burner, consuming say 3 feet per hour, is covered with a perforated copper bulb, about one inch or somewhat less in diameter; in the interior of the bulb the gas receives the necessary admixture of air, and when lighted outside burns with the peculiar blue, lambent flame engendered by the admixture. An apparatus of this kind, which can be used anywhere, only requiring its connection with gas, can be bought for three shillings; it will boil a pint of water in six minutes, and therefore the calculation stands as under—with gas at 3s. 6d. per thousand cubic feet, the average London price, the result being worked out by decimals, some trifle over one-tenth of a penny is the cost of the fuel consumed. In these small figures the comparison does not show economically in a striking form, but we venture to say that no housewife would undertake to light ten fires and boil ten kettles with a single pennyworth of fuel. We shall presently give some figures upon a larger scale, showing the absolute economy of cooking by gas.

We next come to the processes of toasting, roasting, broiling, and frying. These are conducted by reflected heat from a group or circle of burners arranged above the meat or other article that has to be cooked; and some most ingenious French apparatus has lately been introduced in which, by means of reflection from polished surfaces, very economical results have been obtained for every-day purposes. However, it may suffice to say that a gas-cooking apparatus can be purchased for from 15s. to 20s., in which a small joint or a pair of fowls can be roasted by reflected heat below the gas-ring or circle of burners, while above a kettle may be boiled, or vegetables, puddings, or similar matters placed above may be cooked by the same apparatus. And here let it be borne in mind that the waste of fuel in ordinary cooking does not arise only from the lighting of the fire; after the cooking is done the fire has to burn out, and therefore both before the cooking begins and after it is completed there is great waste of fuel and heat. When gas is used, when the cooking is done the gas is turned out at once, and thus only exactly the required amount of fuel is consumed.

We now come to a class of apparatus adapted for "family use," and here more elaborate arrangements are requisite. Sometimes they are simply constructed of iron, but recent improvements have introduced a lining of fire-clay, surrounded outside by some porous, non-conducting medium, which will allow the products of combustion to pass through, absorbing a portion of them, the remainder passing off either by a flue or directly into the external air, the whole being encased in a lining of sheet-iron, and provided with a movable lid, also protected by fire-clay. An apparatus of this sort, 3 feet high, 1 foot 8 inches in diameter, with a single gas-ring at the base, will cook 40 pounds of meat with a consumption of 50 feet of gas. The calculation of cost follows as a matter of course; and here we will give the record of an actual experiment, in which, however, only an ordinary apparatus was used, without the improvements just alluded to. A dinner consisting of mutton, beef-steaks, pork-pie, apple-pie, vegetables, etc., complete, the total weight somewhat exceeding 15 pounds, was cooked with a consumption of 75 feet of gas, at 5s. per thousand feet—the cost of fuel was 4½d.

In some recent experiments on a larger scale still more economical results have been arrived at; but perhaps the instance quoted is sufficient to establish the general principle, *i.e.* the economy of cooking by gas, the requisite facilities being first provided.

We now further proceed to describe a large cooking-range, as it may be termed, capable of turning out a dinner for 100 people—roasting, boiling, baking, frying—in fact, all the requisite processes of the kitchen. This will be 6 feet long, 3 feet high from the ground, and 2 feet deep from front to back—a very ordinary size for a common kitchen range; and the general frame is made of plates of cast-iron, of which we may take the average thickness at half an inch, put together in the ordinary way.

The upper surface is devoted to boiling, stewing, and similar purposes, and contains a number of gas-rings with their burners, or, as they are termed, open gas fires, upon which the various vessels are placed. These may vary in number according to the special requirements of the establishment—we may say from six to ten. In the centre, and rising in a semi-circular form above the level top of the stove, is a hot closet for warming plates, or similar purposes. Below the upper surface, with its open rings of fire, the space is divided into three; on the left is the roasting chamber, similar to that before described, which will cook several joints at once up to the weight of 50 pounds. In the centre is the broiling fire, arranged with a tray a small distance under a gas-ring, and occupying only a few inches in depth; this is large enough to cook say half-a-dozen chops at once, and may be described as the gridiron. Underneath this is an 8-gallon boiler for hot water, self-feeding, with subsidiary cistern and ball-cock specially provided for that purpose. The right of the three divisions is a pastry or bread-oven, large enough to bake about eight quartern loaves or a dozen of pies, the heat being regulated accordingly. What we have described is no theoretical or speculative arrangement; the details were taken from an apparatus we saw in daily work at a well-known public institution.

We may say that similar appliances are at work in many hotels and mansions throughout the country.

We now come to the last branch of our subject, the application of gas to the cooking the daily dinners required for a thousand inmates; and in this case we quote our particulars from an extensive set of the most improved kind which has been at work for a considerable time in one of the London hospitals. In this case the extent of the apparatus requires a separate provision for each particular process—the roasting, baking, and boiling—with the latter, however, the broiling is contained in one frame; and these different arrangements occupy one side of the large kitchen. On entering we first come to the ovens, two in number, each 6 feet high, 3 feet wide, and two feet deep, the gas-ring in each case running round the bottom, while a series of wrought-iron, light, movable shelves, commencing about 2 feet above the ring, extends to the upper part of the oven. Upon these the pies are placed, and each oven will bake fifty pies at one baking, the time varying, of course, with the nature of the dish, from a meat pie to a light pudding.

Next in order along the wall is the apparatus for boiling. The frame, somewhat similar to one just described, on a smaller scale, has fourteen open gas fires, varying from 8 inches diameter up to 12 inches, the larger openings containing a double ring of fire, one within the other. By the arrangement of the pipes and taps, either the inner or outer ring can be used separately, or they can both be used together. The size of the whole frame is 8 feet long, 2 feet wide, and 3 feet high.

Below these open fires another series of rings is arranged for broiling or frying. There is, of course, a horizontal division between the two, and under the second series of fires are

arranged six trays, each 20 inches long and 12 inches wide, sliding in and out; each of these trays will cook 20 chops or thereabouts in a few minutes, will fry fish as required, or do any similar cookery.

Next adjoining is a roasting cupboard, about which we need not go into detail, as it is only used for casual purposes, and somewhat resembles that before described, with the exception of being in two heights, one above another, each 3 feet, with its separate gas-ring.

The series is completed by the great roasting apparatus, or roasting-well as it may be termed, as it is entirely below the floor-line, and covered with a large, hinged, iron cover, level with the floor, and raised by machinery specially designed for this object. The well itself is circular, 4 feet in internal diameter, cased round with fire-clay, and with an external lining of porous, non-conducting material; and into this well descends an open frame of light wrought-iron, upon which the meat to be roasted is arranged on horizontal spits. It will cook 500 pounds of meat in one operation, two hours being the time required, and the consumption of gas 250 feet. There is a large double gas-ring round the bottom; both rings are lighted when the roasting begins; when it has gone on for a certain time one of these is turned off, and the cooking finished with the other. When the meat is done the lid is wound up, and the frame lifted out bodily by means of a crane, the removal occupying but a few minutes. Beneath all is the dripping-pan (approached by a small iron staircase), and this has, of course, to be cleaned out after every roasting.

The entire cost of this large and complete cooking establishment may be roughly quoted at £1,000. We are unable to give any absolute experimental results as to the saving effected by it, as compared with the ordinary methods of cooking, because in this case it superseded an old-fashioned apparatus for cooking by gas already in use, in comparison with which, however, it effects a saving of £300 per annum in meat and gas, as proved by the printed reports of the hospital. Could the comparison be directly made, the results would, no doubt, be startling indeed.

We have thus endeavoured, as far as our limits will allow, to give a general idea of the methods adopted for cooking by gas, from the smallest to the most extensive scale. There are many manufacturers who make this class of apparatus their special study, and the number and variety of the applications of details are almost endless: many illustrated catalogues are published, showing how almost every class of apparatus can be most readily obtained. We have only been able to convey a general idea of the process, the use of which, however, recommended as it is by cleanliness, efficiency, and economy, is rapidly extending.

OBJECT DRAWING.—VII.

It is not deemed necessary here to give any further instructions as to shading. The application of the principles will be further shown in the figures which are to follow. The student is urged to think for himself; to place two or three blocks of wood in various positions, and by moving the light (or, if that be fixed, the models), so as to observe the varying effects of light and shade: the manipulative process is the result of practice, and this may be obtained by covering, at first, small surfaces, and subsequently larger ones, with flat tints of various degrees of darkness, and hatching them in vertical and horizontal directions. He must, however, bear in mind the axiom already laid down, that no amount of shading will remedy bad drawing, and that therefore by far greater importance must be attached to outlines than to shades. In all the lessons, therefore, the principles on which the outlines are based are fully given, so that this important point may not be lost sight of.

Fig. 41 represents two cubes, one of which is parallel to the picture, whilst the other is placed angularly, the upper one being surmounted by a pyramid composed of four equilateral triangles. Of course, the lower cube is to be sketched first, and in this view it has been so often drawn that it will not be necessary to give any instructions concerning it, and we will therefore proceed with our study of the upper objects.

It will be clear that, when the sides of a cube are at equal angles to the plane of the picture, the one diagonal of the base will be parallel, and the other at right angles to that plane. This will be understood by Fig. 42, which is the plan of two cubes, placed in the manner described, A B C D being the plan of the lower, and E G F H the plan of the upper. From this it will be seen—(1) that the diagonal G H of the upper cube is parallel to A D, the front edge of the lower one; (2) that the diagonal E F of the upper cube is at right angles to A D and B C of the lower cube, and therefore to the plane of the picture; and (3) that the intersection of the diagonals of the upper cube is in this position exactly on the intersection of the diagonals of the lower one, as if one axis penetrated the two. Therefore, let *a b c d* (Fig. 43) be the upper surface of the cube. Draw the diagonals *a c* and *b d*, and through their intersections draw *g h* parallel to *a d*, and *e f* in the direction of the point of sight, and projecting beyond *a d* and *b c*. From *e* draw lines to *g* and *h*, and produce them. From *g* and *h* draw lines converging towards *f*. This will be accomplished satisfactorily by making *h f* and *g f* rather shorter than *e g* and *e h*. This, then, will complete the plan of the upper cube, which is thus given in a separate figure in order to avoid confusion in the drawing.

Having brought the sketch (Fig. 41) up to this stage, draw the front edge of the upper cube, which, it must be remarked, must be slightly longer than the edges of the lower cube, since it is rather nearer the eye, being, in fact, the most prominent line in the picture. From the upper extremity of this line draw the edges convergent with the lower ones, and in the same manner draw the back edges of the cube. Draw diagonals, and at their intersection raise a perpendicular, on which mark the apex of the pyramid. Join this point to the angles of the cube, and thus complete the outline. Assuming that this has all been sketched in charcoal, and corrected with chalk (No. 1), the shading may now be proceeded with.

The shadow cast by the projecting angle of the upper cube on the front of the lower one may be rubbed in first; then the shaded side of each of the cubes, and of the pyramid. In this the student will observe the side of the upper cube not being as directly turned from the light as that of the lower (the first being at 45° and the latter at 90°), will not be so entirely prevented receiving light, and will therefore be rather lighter in shade than the other; whilst the side of the pyramid will be still less shaded, owing to the slanting of its surface.

The highest light of all will be at the front edge of the pyramid, and the side nearest the light; the brightest light being on the prominent edge of the cube, which similarly will gradually merge into the general tone of the whole side.

The triangular shape of the cast shadow is caused by the prominent angle of the cube, and the variation of this with the slightest alteration in position is exceedingly interesting to observe.

The group (Fig. 44) which will now form the subject of our remarks, is composed of a cube, on which stands an oblong block covered by the square pyramid.

The following are the proportions of the objects: the cube, 6-inch side; the oblong block, 4-inch side and 12 inches high; and the pyramid 4 inches square at its base. These are the sizes of the models on which these lessons are based, but of course any other proportions would do as well. It will thus be seen that when the oblong block stands on its end upon the cube, a margin is left, and the same width is also seen of the under surface of the base of the pyramid, which rests on and overhangs the oblong block.

The front edge of the cube, being the most prominent line, is, of course, to be drawn first, and the cube finished in the angular view as placed.

Now it is evident that since the sides of the two blocks are parallel, their diagonals will be coincident; that is, the diagonals of the base of the oblong block will rest exactly on those of the surface of the cube, but they will not equal them in length.

Having, then, completed the cube, draw diagonals in the upper surface, mark off on the diagonal which crosses from the most prominent angle the apparent distance of the angle of the upright block, and from this point draw lines to the vanishing-points of the edges of the cube, or at least convergent with them, so that, if produced, they would meet; for as the student advances, he is not expected, in hand-drawing, to really fix the vanishing-points, and rule the lines. A knowledge of the principles and observation of appearances will enable him to draw from objects with tolerable correctness, but, as said before, model-drawing is not intended to serve as a substitute for the study of perspective, but as an application by eye and hand of previously acquired rules, which have been accurately and carefully

worked out: even as writing a letter or other composition is an application of the rules of grammar to which we have become so habituated that correctness comes almost by intuition.

These lines, then, tending to the vanishing-points, are to be drawn until they cut the diagonal which extends horizontally across the cube; and from these points lines drawn in the opposite direction will meet on the first diagonals and complete the base of the upright block.

In the present position of the cube, the one diagonal is horizontal, whilst the other, being at right angles to the plane of the picture, is drawn to the point of sight. As already explained, this is because the object is placed at equal angles, but would not be the case if it were in the slightest degree rotated.

Proceed now to draw the perpendicular edge of the oblong block which is nearest the eye, and having fixed its apparent height, draw lines to the vanishing-points for the horizontal edges. In the present study the objects are placed so that the level of the eye is about the middle of the height of the group; whilst, therefore, the lines of the cube and the base of the oblong block tend upward, those of the top of the block and of the base of the pyramid incline downward.

Now from the left and right angles of the base draw perpendiculars for the two other visible edges of the object, and from the fourth angle draw a perpendicular which will be terminated by lines drawn to the vanishing-points from the extremities of the perpendiculars.

The inner surface of the top of the object will thus be represented. Of course, this would not be visible unless the model were transparent; but, as said before, it is best in the first sketch to assume this, in order to account for lines which are not visible, and to find the places for others which depend on them.

Through the distant and near angles of this inner surface draw a diagonal and produce it, remembering that, as the pyramid is exactly over the cube, the diagonals will be over each other, and therefore this one will converge to the point of sight —as does that of the cube—and the other diagonal will be horizontal, as already explained.

On the first diagonal mark the most prominent angle of the base of the pyramid, which will, of course, be exactly over the front angle of the cube. From this point draw lines to the vanishing-points, cutting the horizontal diagonal in points which will give the angles of the base, both of which again will be over the corresponding angles of the cube. From these points lines drawn to the opposite vanishing-points will give the back lines of the base of the pyramid which are in the view only partially visible.

The apex of the pyramid will, of course, be situated on a perpendicular raised on the intersection of the diagonals. It is advisable, in order to test the exactness of subjects such as this, to sketch the inner surface of the base and draw diagonals, then a line passing through the intersections of each set of diagonals should be an absolutely *vertical* line—the axis, in fact, of the whole group.

The method of shading this object will be given in the next lesson.

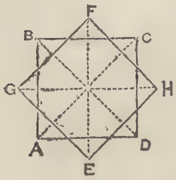


Fig. 42.

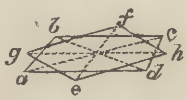


Fig. 43.

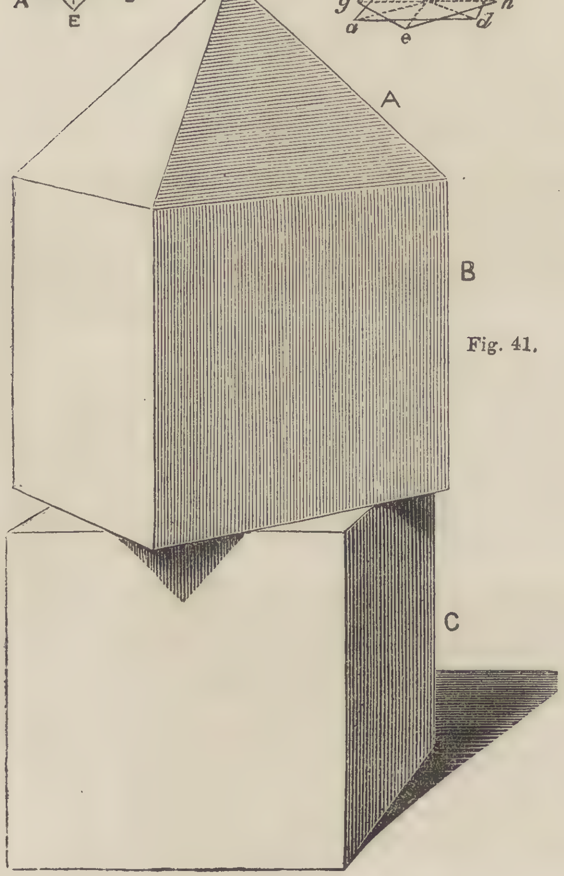


Fig. 41.

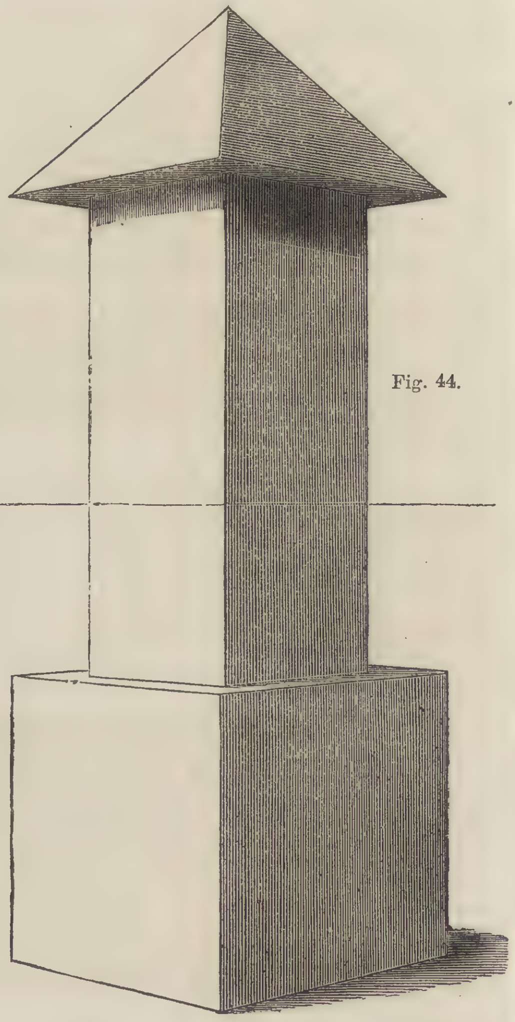


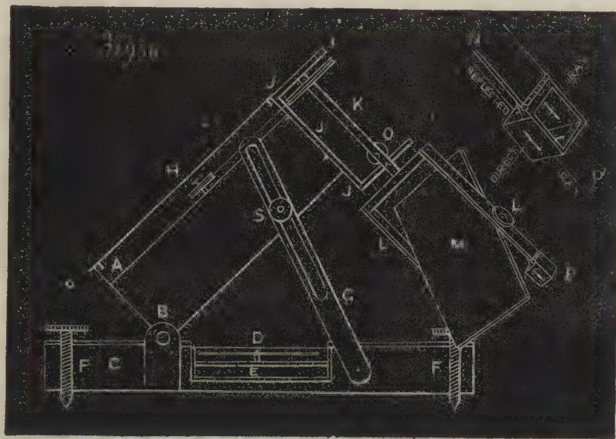
Fig. 44.

OPTICAL INSTRUMENTS.—XII.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SOURCES OF LIGHT.

Maddox's Heliostat is the simplest in construction, and meets every requirement where a small stationary beam of light is required. It consists of a stout base board surfaced with metal, C (Fig. 34), $5\frac{1}{4}$ by 9, by $1\frac{3}{8}$ inches thick, supported on three levelling-screws, F. In the centre of this base board a circular well is sunk in which is fitted a circular levelling box, E, and a compass-box having a $2\frac{1}{2}$-inch needle, D; no iron must be used in the base board. To the upper surface a stout zinc box, A, about 5 inches square, and deep enough to hold an American ship's clock, is hinged at B. This box is set to any angle—to suit the latitude of the place in which the heliostat is set up —by means of two slotted struts, G, hinged at B, to the base, bound by pivots, and fixed to the side of the clock-box by clamp-screws S, working through the slots. A piece of brass with two projecting arms, J J, *set exactly at right angles* to the face of the box, supports the "polar axis," K, which is kept in place by a steel pin passing through a hole in the upper arm, and by two small bevelled friction-wheels, O, resting on the upper surface of the lower arm, through which the axis smoothly works. To the lower end of the axis is attached an oblong metal frame, L L, that carries the reflecting mirror M (the back of which is represented): one arm of this mirror-frame is longer than the other, and terminates in a small cubical box, P, for adjusting the reflector (according to the method of Dr. Curtis, U.S.A.), which is hinged so that it can be placed in front of the side of the mirror, or turned out of the way when the adjustment is completed. The length of the axis and frame depends upon the length of the mirror, but it need not necessarily exceed twelve inches from the upper support to the end of the cubical box.



The polar axis is rotated by means of an endless band passing over a grooved wheel, H, fixed on the axis of the hour-hand of the clock (from which the hands have been removed) and another grooved wheel, I, twice the size of the former, fixed on the axis, K, two holes being pierced in the clock-box to allow the passage of the endless band. The polar axis makes a revolution once in twenty-four hours. If desired, the wheel H may have a dial plate on its upper surface divided into twenty-four hours, and numbered from 12 above to 12 below, for the purpose of setting the instrument to time, the reading being taken from an index screwed to the face of the clock.

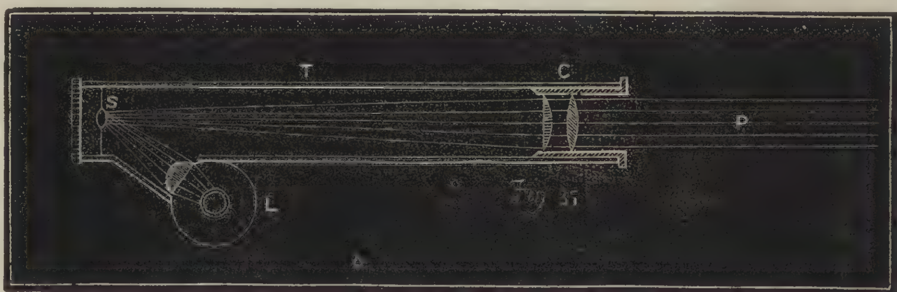
The mirror may also be set by means of a graduated arc fitted to its axis, to obtain adjustment for declination. The index-line is engraved on the arm of the mirror-frame. The zero point on the arc should be taken at 45° from the diameter of the arc that passes through the plane of the mirror's surface. The arc is graduated into half-degrees, for 24 half-degrees to each side of the zero-line; each half-degree being numbered 1, 2, 3, etc., counting each way from the zero-line, so that each half-degree to the left or right of the zero-line gives the necessary adjustment of the mirror for each whole degree of the sun's declination north or south respectively. To make the adjustment, turn the mirror until the index points to the number on the graduated arc which represents the actual degree of declination of the sun for the given day.

These complications are, under ordinary circumstances, rendered unnecessary by employing *Curtis's Heliostat Adjuster*, which is thus described by its inventor :—

P′ gives a perspective view of the cubical box; N shows the arm of the mirror-support to which it is hinged, furnished with a projecting knee, to prevent the box from turning too far back upon the hinge. In the face of this box which fronts to the sun, is a fine slot, running exactly north and south, and upon the under-face is a corresponding slot or line. Then to set the heliostat for time, it is only necessary to rotate the polar rod until the fine ray of sunlight passing through the slot in the upper face falls exactly on the line on the under-face. In a similar manner the side which is turned towards the surface of the mirror has a fine slot cut through it in a direction at right angles to that of the other slot, and upon the opposing surface is a corresponding slot or line. Since these two slots lie in the direction of the polar axis, it is only necessary, in order to set the mirror for declination, to turn it until the reflected beam from its surface which passes through the slot in the side falls exactly upon the indicator slot in the opposite side. After the adjustments are made, the little box may be turned up on its hinges, so as to rest against the supporting arm, and leave the reflected beam from the mirror unobstructed. The dotted lines show the directions of the direct and reflected rays when the adjustments are corrected.

ARTIFICIAL SOURCES OF LIGHT.

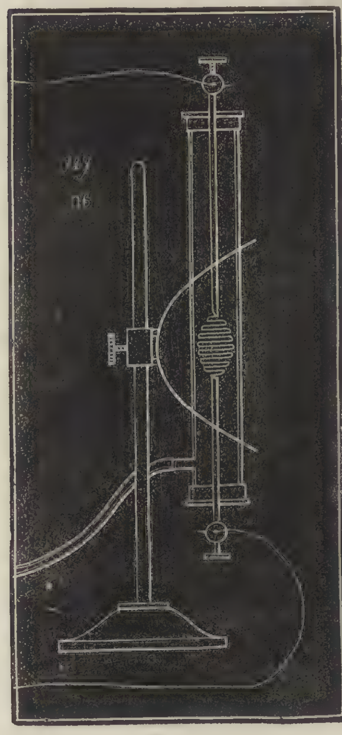
Many heads have been at work within the last few years, trying to discover new compounds, arrangements, and forms of lamps that will give the greatest amount of light with the least amount of trouble and discomfort in preparation, to meet the requirements of lecturers and amateurs who only require a lamp for occasional use, or for those who are nervous as to employing the most powerful light-giving apparatus; others have been trying to obtain still greater power out of the oxy-hydrogen jet, and simpler or safer ways of manipulation; and a few to secure the most intense light attainable by man, that should even out-rival and render him independent of the sun as a source of light, whose face is too often hidden in this our moist and cloudy clime of England, when we most want his assistance. In this bold aspiration—almost as daring in thought as that of the builders of Babel—Wilde has been successful; for, from a pair of carbon points, half an inch square, placed on the top of a lofty building, the light evolved from his magneto-electric machine was sufficient to cast the shadows of the flame of street lamps a quarter of a mile distant, upon a neighbouring wall; while at noon, on a clear day in the month



of March, the direct rays of the sun took *one* minute to darken a piece of sensitive photographic paper, the light emitted at two feet from the reflector of this electric light darkened it to an equal degree in 20 *seconds;* and on a day in June, Mr. Crookes estimated that this electric light had three or four times the luminous and calorific power of the sun at mid-day, at a cost of only a halfpenny per hour, practical not theoretical value, for the driving power of this giant induction machine of Mr. Wilde's invention.

Mr. Crookes further remarks that, "It would be an interesting problem to calculate what would be the result of driving the 32-inch armature required for a 100-ton magnet, with (say) a 1,000 horse-power steam-engine. If the power generated by this machine did not at once burn up the working parts, dissipate the electric lamp and conducting wires with a mighty explosion into space, and strike dead all the attendants with one lightning flash—if it were at all manageable, and were put on a high tower, it would probably give light enough to make London by night considerably brighter than London by day."*

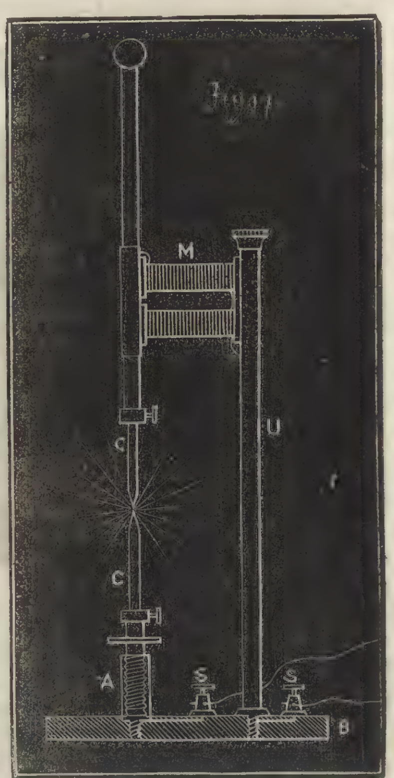
Artificial Star.—The optician employs the sun, the moon, or a star for "adjusting" spectroscopes and other instruments. As these are not always accessible at the moment wanted, an artificial means of obtaining parallel rays for such a purpose is very desirable, and is attainable by an arrangement devised by Mr. Heisch. It consists of a bead of platinum, S (Fig. 35), made by fusing a bit of fine wire with an oxy-hydrogen blow-pipe, which yields a smooth, bright metallic surface, admirably adapted for reflecting a bright point of light. This is bedded in a cork, painted dead black, fitted into a brass cap, that slides into T, a tube about 3½ inches long. To the side of this tube, a little lamp, similar to that represented in Fig. 13, page 156, is fitted by a smaller diagonal tube, so that its light may be concentrated on the bead S. At the other end of the tube a little condenser, C, is fitted, composed of a plano-convex and a double-convex lens, the combined focus of which equals 3 inches; this is focussed on the illuminated bead till any irregularity of surface is detectable either by a normal eye, or when examined by a telescope that has previously been set to the focus of a real star; the arrangement then yields parallel rays, and may be treated as a real star, and be employed as a star is for optical adjustments. This artificial star would be of great use to the spectacle-maker, as a means for focussing his glasses, which I omitted to mention in my previous article on spectacles.



THE ELECTRIC LIGHT.

The electric light may be regarded under three heads—namely, "the vacuum system," "the contact system," and "the arc system," to prevent confusion of ideas as to what *the* electric light proper really is.

The *vacuum light* I mention more as a suggestion for future elaboration, and as suitable for special experimental requirements, when a *moderately brilliant disc of light* can be brought into play without much trouble, by simply lowering the plates of a battery into the exciting solution by means of a windlass, the battery in such case being a "calorimeter" or "quantity arrangement," Smee's being the cleanest and most convenient for this purpose, though the bichromate carbon battery, with an arrangement for pumping air into the bottom of the solution, may be employed. The vacuum light consists of a platinum wire twisted in zig-zag so as to occupy a disc of the required size; the ends are riveted into two stout copper wires that pass through two brass caps and then terminate in binding-screws. The caps are cemented to the ends of a glass tube, that encloses the disc, and is supported in a parabolic mirror, so that the disc stands in the focus of the paraboloid, which in turn is supported on an adjusting rod. To one of the caps a tube is fitted, so that it can be connected with a good air-pump, that the tube may be simply exhausted, or a vacuum of any given gas produced, when a special tint of light is required, or for urging a column of air or oxygen through the tube, according to the nature of the light required. The arrangement is shown in Fig. 36. On the calorimeter being lowered, the resistance offered by the platinum causes the wire to glow, even to the melting-point, and though the turns of the wire do not touch, still, from the property of incandescent wires to appear of increased bulk, the disc looks like a solid mass of light.



Contact Light.—Of late years we have heard of "an electric regulator," worked with *six* cells, which, it is alleged, will produce a beam that supersedes the lime-light. Now as a regulator in no way adds to the battery power—and we have been accustomed to use from twenty to sixty cells for the production of the recognised amount of light—to those who have not been accustomed to get a quart of wine out of a pint bottle, this is rather a startling announcement, especially when we are told that a nine-feet disc can be brilliantly illuminated by this small number of cells. The battery power being so small, it is necessary to keep a pair of very fine-pointed carbon poles touching each other, to produce a small vivid point of light or "voltaic spark," so that we may call this "the contact system" in contradistinction to the arc-producing method, where the carbon poles are pulled apart to produce the "voltaic arc."

A contact-regulator may be thus typified:—An upright, U, attached to a base board, B (Fig. 37), carries an electro-magnet, M, to the poles of which an iron tube is fitted; through this a round polished iron rod smoothly fits, that carries the upper carbon, C, which *rests* on the lower carbon, C′. The lower carbon C′ is clamped by a screw into a socket that is adjustable by a screw fitting A. Both A and M are connected by wires with their respective binding-screws, S, S. When the poles are connected with the terminals of a Grove or Bunsen's battery of six or seven cells arranged for intensity, the current passes through the wire of the electro-magnet M, magnetises the iron tube (which, acting on the iron rod, holds it firm), and then passing through the carbons, causes them to emit a bright electric spark, that continues as long as the points are in contact, for if they burn away so as to leave a space between

* See "A New Era in Illumination," by W. Crookes, F.R.S. (*Quarterly Journal of Science*, October, 1866.)

them, a distance would soon be arrived at, over which the current could not, for want of sufficient power, jump, and the light would be extinguished. The exact point at which the current will pass and the light continue, is termed "the striking distance." To provide for this point not being overstepped, the magnet comes into play, for when the power of the current is weakened by an intervening space existing between the carbon points, the power of the electro-magnet consequently becomes proportionately weakened, and so, losing hold of the iron rod, allows it to slide till the upper carbon again rests upon the lower, and thus re-establishes the intensity of the light and magnetic power also. If more than six cells are used, the carbons may be separated after contact, in proportion to the number of cells employed, by means of the adjustment.

This, however, requires careful watching and manipulation of the adjustment, or the light will be constantly extinguished. In a limited sense such contact arrangements are automatic, but, as a rule, hand-adjusting regulators are more convenient and trustworthy at an equal cost of apparatus, especially if required for lantern demonstrations and spectrum experiments.

SANITARY ENGINEERING.—VIII.

ON VARIOUS APPLIANCES OF GAS TO DOMESTIC AND COMMERCIAL PURPOSES.

GAS BATHS, OR BATHS HEATED BY GAS.

There are many advantages in heating baths by gas—cleanliness, as there is no coal-fire, smoke, or ashes; convenience, as the gas can be lighted at any moment, and therefore the bath is at once available; and economy, as we shall proceed to show.

The simplest and perhaps most usual form of gas bath has a small cistern, holding a few gallons, communicating by two pipes of considerable size with the body of water in the bath, the quantity of water required being about forty to fifty gallons. The bath must be first filled with water to about the level of the upper pipe before the gas is lighted. An ingenious arrangement has been made, by which the double ring of burners or jets beneath the boiler, and just at the level of the floor, may be hinged, so as to swing out clear of the cistern, for convenience of lighting, and then returned to its place. The heated water from the top of the small boiler passes off through the upper pipe into the bath, the cooler water returning to the boiler by the lower pipe, a complete circulation being thus established. It has been proved by calculation — the gas being burnt by meter—that forty gallons of water may be heated to 100° Fahrenheit at a cost of twopence. The objections are that it is always necessary that the bath should be full, or nearly so, before the gas is lighted, and that a very considerable amount of steam is evolved during the process, indicating a certain waste of heat, besides entailing by its presence some amount of actual inconvenience.

To obviate these difficulties several inventions have lately been brought out for heating the water to the requisite temperature by circulation through metal heated surfaces, so that it may be discharged into the bath at once at the temperature required. In these cases the filling of the bath is a gradual process, regulated by the apparatus employed and the temperature of the atmosphere at the time. Our space does not allow us to describe the mechanical particulars of the methods in use, but in some future papers on heating by hot water we may probably go more into detail.

It should, however, always be borne in mind that it is important that the products of gas combustion should never be allowed to mingle with the water, as in that case they are absorbed in considerable quantities; and in some instances the sulphurous acid will impart a distinct flavour to the water. A further advantage of gas baths is that they may be made perfectly portable, and in houses not provided with the necessary convenience, if the gas is only laid on by a flexible tube a warm bath may readily be obtained in about half an hour.

PATENT GAS FLOATS, FOR THEATRICAL PURPOSES.

The use of gas at the foot-lights has for many years obtained in our theatres, but has always hitherto been attended with a certain amount of danger. The draught of a passing dress has sometimes been sufficient to produce a flare of the gas, the dress has caught fire, and serious accidents have been the result. In like manner a glass will sometimes suddenly break, without warning, and any one who has seen the rush made to turn out the gas will readily appreciate the apprehension to which such an accident gives rise. Within the last few years, however, an invention has been introduced which materially modifies, if it does not entirely remove, all these sources of danger and inconvenience.

The range of Argand burners composing the float are arranged upside down, a wrought-iron flue being provided, into which the products of combustion are received and conducted to a special upcast flue, provided for the purpose in the construction of the building. To set the draught fairly in motion a small burner is provided in this shaft, which must be lighted some little time before the burners of the float, to create an updraught; and when this is fairly set going, curious to say, the burners are as efficient burning downwards as when lighted upwards in the ordinary way. Each burner is hinged to a tap, and supported in its position by the glass alone, which surrounds its own special opening in the wrought-iron flue. When a glass breaks under this system, the burner falls by its own weight, turning itself out by the motion, and all risk is thus avoided. It is usual to provide, a few inches above the bottom—which in this case occupies the position of the top of the burner—a covering-sheet of thin wrought iron as a further protection; and so thoroughly is security obtained, that upon this sheet of iron, when all the burners are lighted, a light cambric handkerchief can be laid, without exhibiting the slightest sign of scorching. The advantages are manifest: great security from fire; thorough and complete removal of the products of combustion, a most important matter in connection with the ventilation of theatres; and all this without any increase of cost, as the patent float is in every way as thoroughly efficient for lighting purposes as those heretofore in use.

We may here notice an ingenious little contrivance for bed-room use, to show the "time of night." A gas-burner alight all night in a bed-room is apt to produce a certain closeness of atmosphere, which, if not carried to the point of unhealthiness, is nevertheless very often uncomfortable; at the same time a certain amount of light in a bed-room is always desirable, with the object, if no other, of being able to see "what time it is."

The ordinary gas-bracket is modified in construction by a bent arm attached to an angle in the centre of about 90°, and at the angle is placed a jet, so small as to provide only a little bead of flame. At the end of the bent arm is the ordinary burner and globe; at the end of the straight arm is adjusted a magnifying-glass, so arranged that when the sleeper's watch is hung against the wall, on a hook provided at a proper point for the purpose, by a single glance he can see the time by the light given by the tiny gas jet provided for the purpose. The necessary fittings cost only a few shillings; but for invalids, etc., it provides a certain comfort at a small expense.

GENERATION OF STEAM-POWER BY GAS.

Although not strictly a domestic object, yet in large warehouses and hotels it has been introduced for what may be called household purposes, lifts, etc.

The method adopted is to introduce a small steam-engine, generally of about two-horse power, with a boiler of ordinary construction in all respects but one, and that is, that instead of being heated by a coal-fire, the necessary heat is generated by a series of groups of gas-burners fixed below, which may be described as small compact sun-burners, four or five inches in diameter, consuming the gas mixed with a certain per-centage of atmospheric air, on the same principle as we have previously described in our paper on "Cooking by Gas." The cost of the gas required to work a small steam-engine, as above, has been ascertained by experiment to be about sixpence per hour.

The detail of the machinery for the engine and lift is beyond the scope of our present subject, but the necessary information can be readily obtained from those conversant with similar matters.

The small engine and boiler together will only occupy about fifteen feet superficial of room, and may be taken as costing about £200; and we may mention, as a practical instance of the successful application of the principle, Messrs. Leaf's well-known warehouses in Old Change, where a lift is worked, which

delivers all the goods to the several floors of a lofty warehouse, doing work which, under ordinary circumstances and by manual labour alone, would require from twenty to thirty men. Neither stoke-hole or other appliances necessary for ordinary steam-power are required; and there is this important commercial advantage, that the fire-offices charge no extra rate for this peculiar description of machine.

We conclude our series of papers on gas by a notice of an engine recently introduced, which avails itself of gas as a motive-power, but in a somewhat novel manner: we allude to

HUGON'S GAS-ENGINE.

In all our previous descriptions of various appliances of gas the gas is burnt in the ordinary way, through burners of various forms and combinations, care being always taken where atmospheric air is burnt in conjunction with it that the mixture shall be kept *below* that point at which it becomes explosive, as it is well known that a certain per-centage of admixture of gas with atmospheric air is excessively dangerous; and when we read of explosion of gas it is never the pure gas that explodes, as of itself it does not possess that property, but only acquires it when in the combination above mentioned. In the Hugon gas-engine, however, this particular explosive mixture is utilised as the moving element in the machine. It resembles in its construction a small horizontal steam-engine. It is usually constructed of one or two horse-power; and the motion backwards and forwards of the piston is obtained by filling either end of the cylinder alternately with what may be termed a charge of gas and atmospheric air, mixed in the proper proportions, which is then, by the self-acting motion of the machine, brought into contact with a lighted gas-jet at either end of the cylinder alternately, when combustion, or more properly explosion, at once ensues. No boiler is of course required; the gas has to be laid on, and that is all. The products of combustion are almost *nil*, as the remnant of each explosion is only a small quantity of moisture. The motion is regulated by a fly-wheel, as in the case of an ordinary steam-engine; and upon the shaft of this wheel pulleys can be fixed, and by means of bands or otherwise all the operations of light machine-work carried on—pumping, grinding, hoisting, and all cognate processes, requiring only the adaptation of the requisite machinery.

An engine of one horse-power costs £80, and a three horse-power £130. Scarcely any setting is required. It is almost as easily fixed as a billiard-table; and when not actually at work there is no expense whatever. The consumption of gas for a small-sized engine may be taken at sixpence per hour.

With the sundry matters included in this paper we conclude the subject of gas as a branch of domestic sanitary engineering. We have briefly described the process of manufacture, the method of measurement, and in the series of eight papers upon the subject given the detail, as far as our space would permit, of the different mechanical appliances required for its economical use. In some following papers on warming, ventilation, etc., we may have occasion casually to allude to the subject again, but for the present we dismiss the subject of gas as a branch of domestic sanitary engineering.

TECHNICAL DRAWING.—XLII.

DRAWING FOR STONEMASONS.

FREE-HAND DRAWING FOR STONEMASONS.

FIG. 385.—This moulding is called a *cavetto*, the name of which is derived from the Latin word *cavus*, "hollow." It is a concave moulding, the curvature of whose section does not exceed the quarter of a circle. Its projection may be equal to its height, and should never be less than two-thirds of it. The cavetto, which is the reverse of the ovolo, is sometimes used in the bed and crowning mouldings of cornices.

The method of drawing the cavetto will not require any explanation.

Fig. 386.—The *scotia* is a recessed moulding of an elliptical section, when properly constructed. It is, however, for general purposes formed by the junction of two circular arcs of different radii. This moulding has an effect just the opposite to that of the ovolo or torus, and is sometimes composed, like the latter, of a semicircle only.

To draw the scotia, divide the height of the moulding into three equal parts. From any point, as a, on the line drawn at two-thirds from the bottom, draw the quadrant $a\ b\ e$; from a on the same line set off $a\ c$; from c, with radius $c\ b$, describe the quadrant $b\ d$, which will complete the moulding.

Fig. 387 is a section of the frequently-used moulding called the *cyma recta*. The exact form of this moulding is, to a certain extent, a matter of taste, since the curve may be drawn more or less full, the variation being caused by the radius with which the arcs are struck. The curve most generally used is given here, and the following is the method of describing it:—

Let a and b be the points to be united by the moulding. Draw the line $a\ b$, and bisect it in c; from c and a, with radius $a\ c$, describe arcs cutting each other in d; from c and b describe arcs cutting each other in e; and from d and e, with the same radius, describe arcs meeting in c, which will give the form of the moulding. If it be required that the lower portion of the curve should be more full than the upper, divide the line connecting the two extremities of the section into three equal parts, construct an equilateral triangle on the upper third, and another on the *two* lower portions, then the apices (plural of *apex*, "the upper point") of the triangles will be the centres from which the arcs are to be struck. This and several other methods of describing various mouldings are described and illustrated in Vol. I., page 199.

Fig. 388 is the *cyma reversa*. In this moulding the curve bulges outward at its *upper* part, and it is hence the reverse of the cyma recta. As in the former figure, the exact form is regulated by the taste of the designer. In this and all the curves composed of combined arcs, the greatest care is necessary, so that the one may glide smoothly into the other without showing any break or thickening in the joining, which materially injures the effect. This has already been referred to, and it will be at once seen how the taste, when cultivated by the study of ornamental drawing, will aid in the appreciation of these forms, which add so much to the beauty and gracefulness of the building.

METHOD OF DESCRIBING A RAKING MOULDING.

Raking is a term applied to such members of a building as slope or lie inclined to the horizon. Raking mouldings frequently occur in masonry, and the following example will explain the method of forming them to mitre in a proper manner:—

Fig. 389.—This is the design of a cornice, having part of the moulding level and part inclined, as occurs in the pediment of a building. In this drawing $a\ e$ is the moulding at the angle of the break or projection of the pediment. With this moulding given, we have to find the right section of the ogee in the pediment.

Let $a\ f$ and $e\ e'$ be the two parallel lines which terminate the breadth of the raking, or inclined moulding; and let $a\ k$ and $e\ l$ be the parallel lines terminating the breadth of the moulding which is level.

At a convenient place draw $p\ t$ parallel to the edge $a\ k$ of the horizontal portion of the moulding. Between a and e place any number of points, as b, c, d, and draw $b\ g$, $c\ h$, and $d\ i$ parallel to $a\ f$ and $e\ e'$.

At a, b, c, d, e draw perpendiculars to $e\ l$, cutting the line $p\ t$ in q, r, s.

Now, at any convenient distance, draw a line parallel to $a\ f$. and transfer to it the distances t, s, r, q, p—viz., t', s', r', q', p'.

From each of these points draw lines at right angles to $a\ f$ and $e\ e'$, cutting $a\ f$, $b\ g$, $c\ h$, $d\ i$, and $e\ e'$ in A, B, C, D, E. The curve traced through A, B, C, D, and E will be the right section of the raking moulding.

To find the section through the mitre of the two inclined sides where they meet at the top of the pediment, draw $t''\ p''$ perpendicular to $t''\ e'$, and equal to $t\ p$. Transfer the distances from these to the space between t'' and p'', and draw perpendiculars from s'', r'', q'', p''.

From f, g, h, i draw lines at right angles to $f\ e'$, and through the points where these intersect the perpendiculars—viz., a', b', c', d', and e'—draw the curve which will be the common section of the mouldings at their junction at the apex of the pediment.

The method of constructing simple scales having been given in lessons in "Building Construction," it is not necessary here to repeat the instructions; the subjects in this figure are drawn to the scale of half an inch to the foot. It is advisable to draw the scale on each sheet, as by measuring from this, instead of from the rule, the trouble of calculating how many inches so and so many of the fractions make is avoided, and generally greater accuracy is obtained.

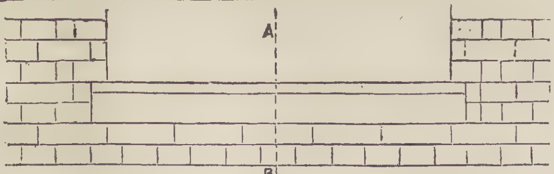


Fig. 390.

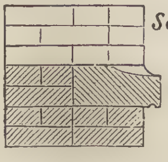


Fig. 391.

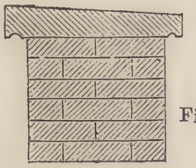


Fig. 392.

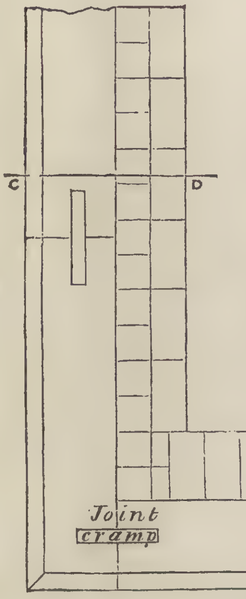


Fig. 393.

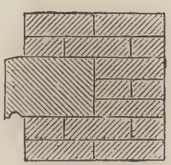


Fig. 394.

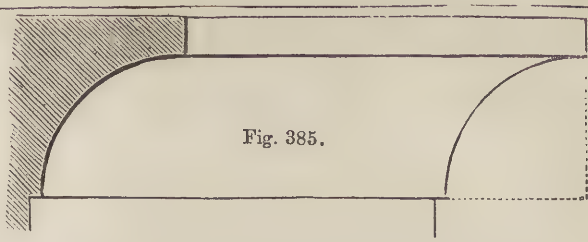


Fig. 385.

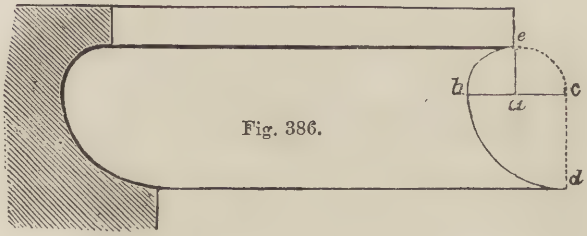


Fig. 386.

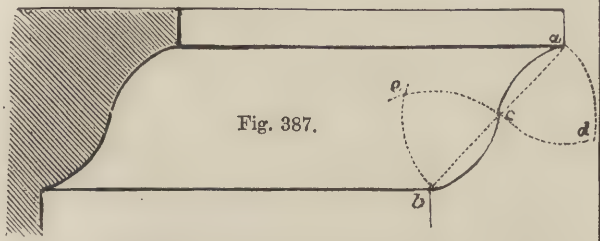


Fig. 387.

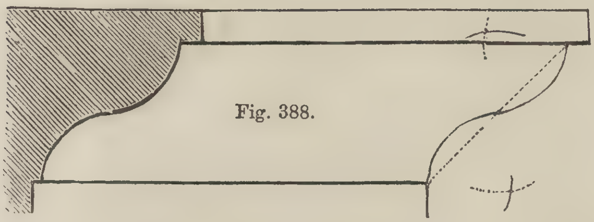


Fig. 388.

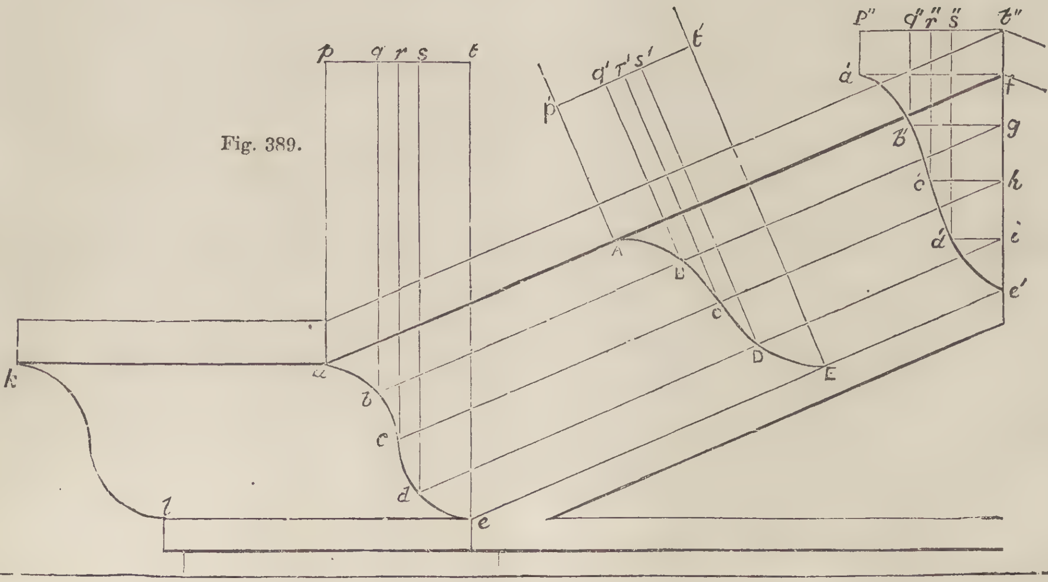


Fig. 389.

As a portion of the present study consists of brickwork, the following brief extract from lessons in "Building Construction" is given, in order to remind the student of drawing for masons of some particulars which, thinking they did not specially concern him, he may have merely glanced over whilst reading the lessons treating of the subject generally :—

"Bricks may be considered as artificial stones, and seem to have been used from the very earliest period in the history of man. Their average size in this country is a trifle less than 9 inches long, $4\frac{1}{2}$ inches wide, and $2\frac{1}{2}$ inches thick. Their uniformity in size enables builders to describe the thickness of walls by the number of bricks extending across them; thus a slight brick partition wall, being formed of bricks lying on their broad side, with their length in the direction of that of the wall, is called a 'half-brick thick,' its depth from one side to the other being $4\frac{1}{2}$ inches. A wall in which the length of a brick extends through the thickness is called a 'one-brick thick.' A wall 14 inches through is called a 'brick-and-a-half thick,' though, to speak more accurately, it would be $13\frac{1}{2}$ inches—that is, 9 for the whole brick, and $4\frac{1}{2}$ for the half. An 18-inch wall is said to be a 'two-brick thick,' and so on."

Fig. 390 is the elevation of the lower part of a window, showing the window-sill.

It will be seen that the wall is built in old English bond, and that the stone sill is equal in height to two courses of brickwork. The opening of the window is four feet wide; the brickwork covering the ends of the sill to the width of two inches on each side. It will also be observed that in order to avoid the joint in the courses of bricks at the sides coming immediately over each other (which would occur if two bricks placed as headers were placed upon one stretcher), cut bricks, called "closers," are used. This has been explained in lessons in "Building Construction."

Fig. 391 is the section in A B, and shows the manner in which the sill is sloped off, or "weathered," and throated underneath. Both of these terms will be explained in connection with the next figure.

Fig. 392 is a section of a *coping.* This term is used for the series of stones used as the capping or covering of a parapet or wall. The name is generally applied to a plain, slightly projecting course, and *cornice* to a larger moulded coping.

Copings are worked with a plain horizontal bed, two vertical faces, and an inclined or "weathered" upper surface, either forming an obtuse angle with the inner and narrower face, and an acute angle with the outer wider face, or slanting off from the middle towards each side, which latter is technically termed a "saddle-back coping." In both cases they are made to project over the wall or parapet on both sides, and in the projected part of the bed, under the edge or edges towards which the inclination is given, a channel or groove, called a "throat," is cut, to intercept the water in its inclination to run inwards towards the wall. To protect the separate stones of a coping course from the danger of being displaced by high winds or other accidental causes, and to form a chain through its whole length, the stones are linked together by cramps of copper or iron let into them and run with lead. These metals, however (says Mr. Hoskings), especially the iron, for the most part act very injuriously, from their exceeding susceptibility of atmospheric changes, and their greater or less tendency to oxidation; indeed, the stone invariably suffers more than the work benefits from the metal cramps. Tenons, dowels, joggles, or dovetails of stone, or of hard wood, or cast iron, applied so as to be protected from the weather, would be far better, and would answer every desired purpose sufficiently.

A *string course*, shown in plan in Fig. 393, and in section in Fig. 394, is meant to protect a set-off in a wall, by projecting over its lower face in the manner of a coping.

The beds are worked parallel, and the outer face vertical, or at right angles to them, but so much of the outer surface as protrudes from the wall is "weathered," or sloped off to carry the water away; and, for the reason already stated with regard to copings, the lower bed just within the outer face is throated. A string course cramped or dovetailed in the bed forms an excellent chain around a brick wall, but the part of it in the wall should be of the exact thickness of one, two, or more courses of the brickwork. The method of drawing these examples is so very simple, that it is not thought necessary to give any instructions on that head.

SEATS OF INDUSTRY.—XVII.

COVENTRY.

BY WILLIAM WATT WEBSTER.

A FEW of the leading facts relating to the history of silk culture and silk manufacture may not inappropriately preface an account of the city of Coventry, so long a centre of the silk manufactures of England. In the Old Testament there are three references to silk as an article of clothing: one in Proverbs, which is believed to have been written 1,000 years B.C.; and two in Ezekiel, which dates from about the beginning of the sixth century before Christ. But silk manufacture can be traced back to a far more remote antiquity than the Proverbs of the merchant king of Israel. According to the traditions of the Chinese, the rearing of the silkworm and the weaving of silk into robes formed part of the occupation of the ladies of the royal household of China 2,700 years before the Christian era, and the discovery and utilisation of the fibre is ascribed to the consort of one of the celestial emperors. The silkworm, indeed, would appear to be indigenous to China; or, to speak more strictly, to Serica or Serinca, that part of India lying beyond the Ganges. "Seres is the name given by the Greeks and Romans to the inhabitants of these remote regions," says Dr. Lardner, and "it is now so generally admitted that the Seres of the ancients are the Chinese of the moderns, that it is unnecessary to enter into any discussion in proof of this belief. *Se* is the name for silk in the Chinese language; this, by a faulty pronunciation, not uncommon in their frontier provinces, acquired the final *r*, thus changing the word into *ser*, the very name adopted by the Greeks. We can, therefore, hardly doubt," he adds, "that these obtained the name, as well as the material itself, first from China." The Latin name for silk was *sericum*, of which *silicum* is supposed to be a corruption. For a remarkably long period the Chinese seem to have retained a complete monopoly of the cultivation of silk, and even of its manufacture. In the time of Aristotle the inhabitants of the island of Kos were in the habit of unweaving the heavy silk fabrics of China, purchased from Persian and Phœnician merchants, and of re-spinning and re-weaving them into lighter cloths. This process is said to have been invented by Pamphila, and to have been the origin of silk gauze. Alexander the Great brought woven silks to Greece from Persia, and in the works of Aristotle, his tutor and friend, is to be found an accurate description of the silkworm. But it was not till about the year 550 A.D., in the reign of Justinian I., that the cultivation of silk was introduced into Europe by two Persian monks who had visited India as missionaries. "There," says Robertson, the author of "Disquisitions on the Commerce of India," "amidst their pious occupations, these monks viewed with a curious eye the common dress of the Chinese, the manufacture of silk, and the myriads of silkworms, whose education, either on trees or in houses, had once been considered the labour of queens. They soon discovered that it was impracticable to transplant the short-lived insect, but that in the eggs a numerous progeny might be preserved and multiplied in a distant climate." Carrying off a quantity of the eggs of the bombyx concealed in a hollow cane, they returned to Persia, and from thence sent a communication to the Emperor Justinian, to the effect "that the Romans need not any longer be obliged to purchase raw silk of the Persians, nor of any others; for having lived long in a country called Serinda, they now assured him that, although the origin of raw silk was till now a secret from the West, it proceeded from certain worms taught by Nature to spin it out of their own bowels; and that though it was impracticable to bring those worms so far alive, yet it would be easy to procure their bags, which would produce the worms." Justinian took the manufacture into his own hands, and appointed the monks to superintend the rearing of the worms. Shortly after this period silk culture was established in Greece, and especially in Peloponnesus, and a great trade was carried on in silk goods by the merchants of Venice, who formed the channel through which the silk produce of Greece was transferred to the west of Europe. In 790 Charlemagne sent two silken vests to Offa, King of Mercia, as a present. Up to the middle of the twelfth century the far East, Constantinople, and Greece were the sole sources from which silk was supplied. It was in 1146 that Roger II., King of Sicily, having conquered Greece, brought to Palermo a band of prisoners who

had in their own country been employed in rearing and weaving silk, and by their means laid the foundation of this industry in Italy, from whence it subsequently spread to France and Spain.

At the marriage of Margaret, daughter of Henry III. of England, with Alexander III. of Scotland, in 1251, 1,000 English knights clad in silken raiment were present; but their robes must have been spun and woven, if not made, abroad, as several centuries had to elapse before any silk manufacture was established in Britain. About the beginning of the fifteenth century a company of silk-women was established in London, and in 1455 an Act of Parliament was passed which, "upon the heavy complaint of the women of the mystery and trade of silk and thread workers in London, that divers Lombards and other foreigners enriched themselves by ruining the said mystery," directed "that no wrought silk should be brought into England by way of merchandise for five years to come." During the reign of Mary, every one below the dignity of a magistrate was prohibited, under the penalty of three months' imprisonment and a fine of ten pounds, from wearing "silk in or upon his or her hat, bonnet, or girdle, scabbard, hose, shoes, or spur-leather." Numerous sumptuary and protective laws were subsequently passed which materially affected the progress of the silk trade and manufactures in England. It was in the reign of James I. that the weaving of broad silks was first commenced in this country, and by 1629 this branch of industry had increased to such proportions that the silk throwsters of London were incorporated. But the silk manufactures of England never attained any great importance until after the revocation of the Edict of Nantes. In the year 1685 a large number of French Protestant refugees, including many skilled silk-weavers, settled in Spitalfields, London. These foreign artisans introduced the manufacture of alamodes, lustrings, brocades, satins, velvets, and other fabrics that previously had to be imported. The next important step in the history of the English silk manufactures was the erection of a great silk-throwing machine on the Derwent, in 1719, by Sir Thomas Lombe, of Derby, and his brother John, constructed from drawings which the latter had surreptitiously obtained at Leghorn, then the principal centre of the Italian silk trade. In 1715 John Lombe went to Leghorn to observe the silk machinery in use there, and, if possible, to bring the secret home with him to England. Finding that he could not obtain any useful knowledge by watching the machinery during the hurried visits strangers were allowed to make to the mills, Lombe, who was a very young man, disguised himself as a youth out of employment, and with the assistance of the priest who acted as confessor to the proprietor of the works, and whom Lombe is believed to have bribed heavily, he got an engagement to attend a spinning-engine called a "filatoe." Concealing his dark-lantern, tinder-box, and mathematical instruments in a hole below the stair where he slept, Lombe night after night made drawings of the different parts of the machinery, which his priestly accomplice handed over to the Italian agents of the Messrs. Lombe, for transmission to England in bales of silk. When the whole of the machinery was carefully drawn, Lombe got on board a ship, and although his flight aroused instant suspicion, and an Italian brig was despatched to intercept him, he arrived safely in England. "There is a tragical story told of his death," says Lombe's biographer, "which is likely enough to be true. It is said that the Italians, when they heard of the whole affair, sent over a female to England to poison him. Lombe had brought over with him two Italians, who were accustomed to the manufacture he had risked so much for. The woman succeeded, through the means of one of them, in administering a deadly poison."

Sir Thomas Lombe received a patent for his silk machine, and although, on the expiration of the patent, Parliament refused to renew it, he obtained a sum of £14,000 "as a consideration for the eminent services he had done in discovering, in introducing, and bringing to full perfection, at his own expense, a work so useful and beneficial to the kingdom." But however profitable this undertaking may have proved to Sir Thomas Lombe, the best authorities are agreed that the establishment of throwing machines was indirectly one of the most formidable obstacles to the development of the silk manufactures of this country, as the existence of throwing-mills was successfully urged for nearly a century as a sufficient reason for levying oppressive duties on thrown or organzine silk. And yet it can hardly be doubted that the silk manufactures of England have been largely indebted to the enterprise and the sharp practice of the Lombes.

It is impossible to fix the precise date when spinning and weaving were first introduced into Coventry, but the local annals of the city prove that it was celebrated for the manufacture of cloth caps and bonnets, and a kind of thread known as "Coventry true blue," early in the sixteenth century. From 1581 till 1694, when the Turkey trade was destroyed, the manufacture of woollen broadcloths of various descriptions was the staple trade of the town. It is not improbable that the ribbon trade was carried on in Coventry at the latter date, or, at least, shortly after, as in 1705 we find that William Bird, silkman, was mayor of the city. It is supposed that several of the silk weavers who arrived in England in 1685 settled down in Coventry, and laid the foundation of its ribbon manufactures. At first this industry was carried on upon a small scale, and it was only by degrees that Coventry rose to be the chief emporium for ribbons in England.

The silk-trade of Coventry has passed through many vicissitudes, it having been affected, not only by the ordinary calamities that depress other trades, but also by changes in the fashions, and other causes peculiar to itself. About a century ago, the manufacture of watches was introduced into Coventry, and so greatly has this industry prospered, especially during the past half-century, that a greater number of watches are now annually made in this city than in London, while the quality of the article produced is not surpassed by the watch manufacturers of London.

Coventry is situated on the Sherborne, an affluent of the Avon, 85 miles N.W. of London, and 18½ miles S.S.E. of Birmingham. The name would seem to denote that the city took its origin from a convent, but of this no authentic proof can be given. It is believed, however, that Leofric, Earl of Mercia, and his wife, the celebrated Lady Godiva, founded a Benedictine monastery there about the year 1044. The story of Lady Godiva, which is first mentioned by Matthew of Westminster, in 1307, or some two hundred and fifty years after the time when that lady lived, may be purely legendary, but it has contributed to spread the fame of Coventry abroad through the world, at least as much as its ribbons and watches. Sculptors, painters, and poets have so frequently illustrated this fictitious or real incident in the history of Coventry, that it is unnecessary to repeat the details of the story here. Every third year the memory of Godiva's devotion to the people is still celebrated at Coventry by a procession, and up till the passing of the Municipal Reform Act the ceremonial was graced with the presence of the mayor and corporation in their official robes. It was not a feat suitable for realistic representation, and we are not sorry to hear that the procession is losing favour with the inhabitants. In this connection it may be mentioned that Coventry was celebrated in the fifteenth century for the religious mysteries or plays performed there by the Grey Friars in the presence of the kings, who then resided in the city, and also for the gorgeous pageants and processions that its inhabitants indulged in. Several parliaments were convened at Coventry by the ancient kings of England; one held in 1404 being known as the *parliamentum indoctum*, from the fact that lawyers were prohibited from taking part in its proceedings; and another which sat in 1459 was called *parliamentum diabolicum*, on account of the number of acts of attainder passed by it. The city was incorporated by Edward III., and the first mayor was chosen in the year 1345. Coventry has sent two members to the House of Commons since 1453. In Roman Catholic times it possessed a large and handsome cathedral, which was destroyed in the time of Henry VIII. During the civil war of the seventeenth century Coventry was conspicuous for the support it gave to the Republican cause.

The more modern quarters of the town of Coventry are well built and regular, but it still preserves several narrow and crooked streets, with houses in the style of the fifteenth and sixteenth centuries, composed of heavy wooden beams filled in between with bricks and plaster, and in some cases having peaked upper storeys, projecting far over the under-floor, and darkening the thoroughfare. Great improvements have been effected in the city within the past few years. Among the most remarkable of the public buildings are St. Michael's Church, a

masterpiece in the lighter Gothic style, with numerous windows filled with ancient stained glass, and having a fine spire 363 feet high; Trinity Church, with a spire 237 feet high; and Christ's Church, a modern building, attached to the elegant spire of the Grey Friars Monastery. These are the "three tall spires" of Coventry. St. Mary's Hall, erected in 1450, also deserves notice, as it is one of the finest specimens of the ornamental work of the fifteenth century in England. The roof of this hall is finely and grotesquely carved, the walls are hung with ancient tapestry, and it is lighted by a great painted window. The charitable institutions of Coventry are numerous and well endowed. Of these we may note Sir Thomas White's charity, founded in the reign of Henry VIII., which possesses an annual revenue of between £2,000 and £3,000; the Bablake Men's Hospital, with estimated income of £1,500; and the Bablake Boys' Hospital, with an income of about £940. It has also a Free Grammar School and several charity schools. In ancient times Coventry was surrounded by walls three miles in circumference, and three of the gates and a portion of the walls still remain standing. Around the city there are 2,300 acres of common land, on which each of the freemen has a right to pasture three cows.

MINING AND QUARRYING.—XI.

BY GEORGE GLADSTONE, F.C.S.

IRON.

SIEMENS' REGENERATIVE GAS-FURNACE—BESSEMER PROCESS OF PUDDLING—PIG-BOILING—THE FORGE—MACHINES FOR SQUEEZING AND HAMMERING THE PUDDLED BALL.

It was seen in the last article that puddling, as ordinarily conducted, is both an expensive and laborious process. We have now to speak of some very different arrangements which are coming into more general use, by which some of the objections to the old process are more or less obviated.

First, we must consider the adaptation of Messrs. Siemens' regenerative gas-furnace to this operation, by which some substantial advantages are gained. The first of these consists in economy of heat. In the ordinary puddling-furnace there is a great waste of this, as is sufficiently evidenced by the flames issuing from the chimneys, which at night may be seen illuminating all the country round; but in Messrs. Siemens', the heated gases pass from the hearth to the regenerators, so as to do double duty, the heat being so completely utilised that the flue always remains cool.

The arrangement adopted is shown in Figs. 11 and 12. The gas-producer and the regenerator are situated below, A and B being the channels for the passage of the heated gas to and from the hearth C, which is provided with water-bridges, D D, the overflow from which passes into the tank E. A current of air passes through the apertures F F (Fig. 11), over the water in the tanks; and this, coupled with the evaporation of the water, keeps the iron plate forming the bottom of the hearth cool. G, G are ovens for heating the iron for the next charge, preparatory to its being put in the hearth, by which a considerable saving of time and heat is effected, less than one hour being sufficient for the whole operation. Secondly, the reduction in time probably accounts partly for the fact that there is no loss of metal in puddling by this process; while the facility with which the gas-flame can be made either reducing or oxidising at pleasure, reduces the chance of loss to a minimum. One of these furnaces, in eighty heats, has actually returned more puddled metal than the pig-iron supplied, the actual figures being 38,808 pounds, against 38,668 pounds. Now, as the weight of the impurities removed will be something considerable, even allowing for no loss of iron at all, it is evident that something more than this must be supplied by way of compensation from the oxide used in fettling. By the ordinary process no account is taken of any such gain, as the net result always shows a considerable loss.

A third advantage which has been incidentally alluded to is the reduction of time, or, to put it in another form, a reduction of labour—eighteen heats have been turned out from three furnaces in twenty-four hours, against twelve, which is the full work of the ordinary furnace. Lastly, the quality of the produce is superior, as there is no risk of any impurities being carried by the draught from the fuel to the hearth.

An altogether different process must now claim our attention. It is commonly known by the name of the inventor, Mr. Bessemer. The principle which lies at the foundation of it is that of raising the iron to a very violent state of ebullition, by forcing air through the molten metal, and thus bringing every particle of it in contact with the oxygen. It was attended at first with numerous practical difficulties, but these have been overcome in time, and the process is now very largely used. In the course of a few minutes the puddled iron is obtained from the crude pig, without the intervention of the puddler, the whole being done by machinery, which only requires the attention of one man.

The important parts of the apparatus required are the converter, a hydraulic machine for moving it, and a blowing engine. The form of the converter will be best understood by a reference to Figs. 13 and 14, which represent a vertical section and an elevation, showing the trunnions upon which it swings, and the arrangement for introducing the blast. The converter is an ellipsoid vessel of iron of about 13 feet in height, consisting of two separate portions firmly bolted together. The lining, C, has to be renewed from time to time, generally after seventy-five or eighty charges, and for this purpose the bolts have to be unscrewed. The lining consists of fire-clay and pounded sandstone, well mixed, and tightly pressed down upon the iron frame; it must be carefully dried, and any cracks that may appear made good before using. B, B are twyers (generally seven in number), which are made of fire-brick, pierced with small holes; these have to be renewed about every third time. The blast is brought to them through the pipe A A, passing through one of the trunnions, which is made hollow for the purpose; by this arrangement the blast can be continued whatever may be the position of the converter, the essential importance of which will be seen presently. The hydraulic engine for moving the converter is connected with the opposite trunnion at D, so that the man can work it from a distance.

The charge of pig-iron (about 3 tons) is introduced into the converter in a molten state; it might be run direct from the blast-furnace, but practically it is more convenient to remelt the iron for the purpose. In receiving the charge the converter is thrown into a horizontal position, with the mouth E turned upwards, and while the vessel remains thus the iron will rest upon its side without touching the twyers. The blast is then turned on, and the converter raised again to the vertical position, when the iron will cover the twyers to about the depth shown in the drawing; but had the blast not been supplied first, the iron would have got into the twyer-holes and choked them up. The iron immediately begins to boil violently, filling the whole converter, and throwing out from the mouth a shower of burning scoriæ and iron. In about a quarter of an hour or twenty minutes the whole of the carbon has been burnt, and the silicon and earthy matters separated; the iron now, almost as limpid as water with the intensity of the heat evolved, being ready to be poured out into the moulds. For this purpose the converter has again to be tilted over, the blast being kept on in full action until the twyers are above the surface of the metal.

The loss in weight during the process (including the preparatory melting) amounts to about 22½ per cent., so that in this respect it is not economical; a good deal of iron is, however, thrown out of the converter in the shape of sparks, which is of course recovered. The separation of the silicon seems to be almost perfect, and the carbon also is much more thoroughly removed than is practicable by the ordinary process; unfortunately, however, the sulphur and phosphorus are not affected to any appreciable extent, so that the Bessemer iron retains the most deleterious of all the impurities. This one circumstance has rendered the process inapplicable to the common pig-irons, and has practically limited it to those made from the hæmatites and other very fine ores. It is therefore principally valuable in the manufacture of steel, and will have to be referred to again when treating of that article.

Some iron-masters substitute "pig-boiling" for the refining and ordinary puddling; one operation thus suffices instead of two, but economically there does not seem to be much difference in the result. The furnace is made upon the type of that for puddling, except that the hearth is deeper; some cinder is added to the charge of pig-iron, and a higher temperature is employed. There is a more violent action in the giving off of

the carbonic acid, which has given rise to the name adopted, but otherwise the process is very similar.

In some works the waste heat from the puddling-furnace is utilised in the raising of steam, and in others the waste gases of the blast-furnace have been used as a substitute for fuel in puddling. Such arrangements as these for effecting economies in the supply of heating power deserve to be more carefully considered when planning the erection of works.

We must now consider the treatment to which the puddled ball is subjected, in order to convert it into bar or sheet iron. The part of the establishment to which we now pass is called the forge. The ball, as may readily be imagined from the description of its preparation given in the last article, though consisting of malleable iron, is far from being a solid mass, and contains more or less of the cinder mixed with it. This has literally to be beaten and crushed out.

The forge contains a variety of hammers, squeezers, and rollers, of great weight and power. Opinion is divided as to the respective merits of hammering and squeezing, and both plans continue in such general use that they cannot be passed over: in either case the process is termed "shingling," and the workmen "shinglers."

We will consider first the squeezers, of which there are a great variety of forms, but mainly referable to two distinct types. The simpler will be readily understood by a reference to Fig. 15. The puddle-ball, while yet quite hot, is placed upon the iron plate B, and at every revolution of the fly-wheel, which is driven by steam, the massive upper jaw A comes down with great weight upon the ball, forcing the particles of iron into close contact, and at the same time expelling any cinder that may be mixed up with it. The jaws are very commonly grooved or toothed, rendering them eminently suggestive of those of a crocodile, so that this form of squeezer very generally bears that name. All that the shingler has to do is to move the ball in the intervals of pressure, so that all parts of it may be thoroughly acted upon. The machine can be driven at great speed, so as to give the jaw from eighty to ninety actions per minute. As much as 100 tons of iron will pass under one of these squeezers per week. By a slight modification of the arrangement, a double-acting machine can be made; the beam C being armed with another jaw on the opposite side of the pivot D, so that two balls may be squeezed at the same time.

The other form of squeezer is made upon the principle of compelling the ball to pass between rollers, which approach each other more closely as they complete their circuit. The horizontal rotary squeezer consists, for instance, of an iron drum,

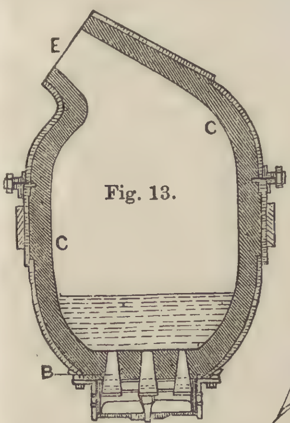


Fig. 13.

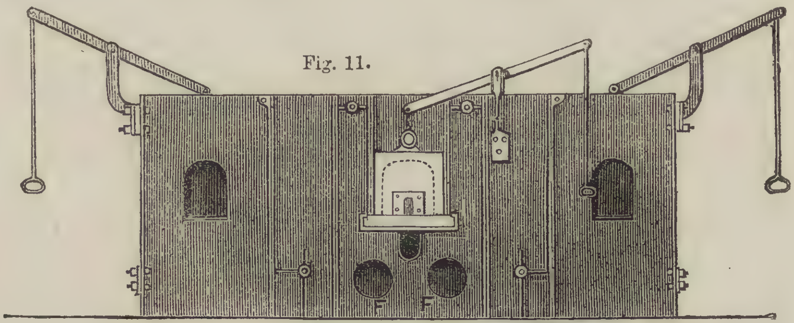


Fig. 11.

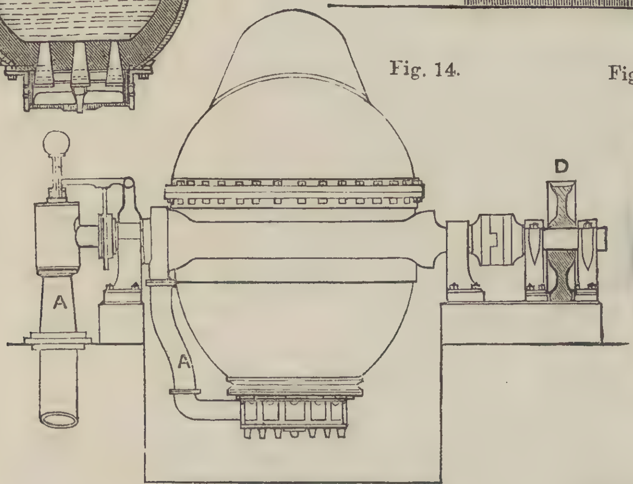


Fig. 14.

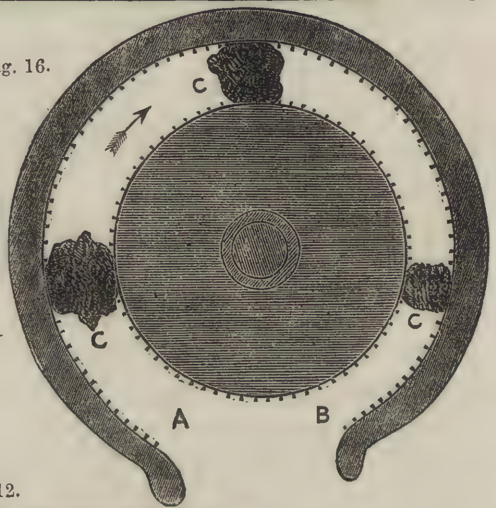


Fig. 16.

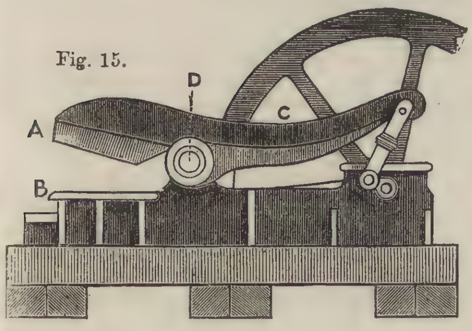


Fig. 15.

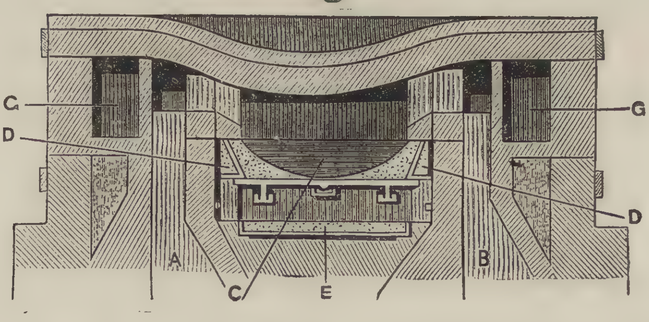


Fig. 12.

open on one side, with an iron cylinder within, which turns upon a centre slightly differing from that of the drum itself. The space between the cylinder and the drum will therefore be less in one part of the circuit than the other. The puddled ball C is inserted at A (Fig. 16), and the revolution of the cylinder, which is armed with small teeth, carries it forward in the direction of the arrow through the narrower portion, and ejects it at B in a highly compressed state.

Other shingling machines are so constructed that the mass of iron falls down between three or more revolving cylinders, so arranged and of such form that the space through which the ball passes in its descent is constantly narrowing; the action upon the metal is similar to that of the rotary engine, the difference consisting in the mechanical arrangement.

The use of hammers is of older date than the first adoption of squeezers; but we have deviated from the chronological order because of some modern inventions, which enable pieces of iron of a size never before attempted to be forged by means of the hammer.

The older forms are called tilt-hammers and helves. The former consists of a long beam working on a pivot, to the longer arm of which is attached a head, below which lies the anvil. The hammer is driven by a wheel furnished with cams, which, as they revolve, press down the shorter arm and raise the hammer-head. These are generally of comparatively light construction, and are worked at a considerable speed.

The helve is a much more ponderous instrument; the beam is made of cast-iron, to which is fitted a wrought-iron hammer-face, the two together weighing ordinarily from 3 to 5 tons, but up to 10 tons in some instances. The beam works upon a pivot at the extreme end, and is lifted by a wheel, the cams of which lay hold of a projecting portion immediately adjoining the hammer-head. These have a less length of stroke, and work more slowly, rarely exceeding one blow every second, but their great weight renders them very effective instruments. The hammers are indeed considered to turn out a better article than the squeezers, but they are worked at greater expense, the wear and tear of the head and the anvil being very great. These, indeed, seldom last more than a week.

The most powerful instrument of all, however, is the steam-hammer, with which Nasmyth's name is naturally associated, though other inventors have patented modifications of the same principle. The hammer-head is attached to the end of the piston-rod, and is raised and lowered by the direct action of the steam in the cylinder. So well-known a machine does not require detailed description here, beyond pointing out its special advantages in connection with the forging of iron. When a ball of metal is put under one of the other hammers, it is subjected not merely to a heavy, but at the same time sharp blow, and no means exist of regulating the force of it except at a loss of power; whereas in the steam-hammer the force can be applied as gradually as the workman pleases. An imperfectly puddled ball will thus fly to pieces under the blow of a helve, which will not suffer under the more gentle, though not less efficient, action of the steam-hammer. They are now almost universally adopted in the very largest forgings.

NOTABLE INVENTIONS AND INVENTORS.

XIX.—GLASS-MAKING.

BY JOHN TIMBS.

In the whole range of human invention it would be difficult to point to a more ingenious or interesting result than the manufacture of glass. Although perfectly transparent itself, not one of the materials of which glass is made partakes of that quality; a combination which may, at the period of its invention, have been as astounding as the identity of carbon and the diamond, established by the chemical philosopher of our time.

Glass was long considered to be a strictly chemical combination of its ingredients; such, however, is not the case, the alkali in common glass being in a very imperfect state of combination, and the free alkali being obtainable from it. Faraday considered glass rather as a solution of different substances, one in another, than as a strong chemical compound; and that it owes its power of resisting chemical agents generally to its perfectly compact state, and the existence of an insoluble and unchangeable film of silica, or highly silicated matter, upon its surface. ("Bakerian Lecture," 1830.)

The origin of glass is uncertain. It is reputed to have been discovered by accident. This inference is strengthened by the fact that it is scarcely possible to excite a fire of sufficient heat for metallurgical operation without vitrifying parts of the bricks or stones of the furnace. Of such imperfect vitrification the "glass" occasionally dug up on the sites of buildings destroyed by great conflagrations is a specimen. (Apsley Pellatt, on "Glass-making.") Josephus claims the discovery for the Israelites. Herodotus and Theophrastus confirm the fact of the use of glass having been known in the earliest periods of civilisation, and of the establishment of glass-works in Egypt and Phœnicia, and even in India, where rock-crystal was employed in its composition. Glass is mentioned in the Book of Job: "Hast thou with him spread out the sky, which is strong, and as a molten looking-glass;" but this expression may have been intended, in the original Hebrew, to refer to the metallic speculum.

To the Phœnicians was long ascribed the discovery. It is stated by Pliny that "some mariners who had a cargo of *natrum*"—(salt, or, as some have supposed, soda)—"on board, having landed on the banks of the river Belus, a small stream at the base of Mount Carmel, in Palestine, and finding no stones to rest their pots on, they placed under them some masses of natrum, which, being fused by the heat, with the sand of the river, produced a liquid and transparent stream: such was the origin of glass." However this may have been, the sand which lay for half a mile round the river was peculiarly well adapted for the making of glass. The Sidonians, in whose vicinity the discovery was made, took it up, and in process of time carried the art to a high degree of excellence; they are even said to have invented glass mirrors. It is at the same time a curious fact in the history of discovery, that the manufacture of glass was, not many years since, unknown at Sidon, where it is reputed to have been first manufactured. Anciently, however, Sidon was famous for its glass. The above account by Pliny is, in substance, corroborated by Strabo and Josephus. Upon the above discovery Cuvier eloquently says:—"It could not be expected that those Phœnician sailors who saw the sand of the shores transformed by fire into a transparent glass should have at once foreseen that this new substance would prolong the pleasures of sight to the old; that it would one day assist the astronomer in penetrating the depths of the heavens, and in numbering the stars of the Milky Way; that it would lay open to the naturalist a miniature world, as populous and rich in wonders as that which alone seemed to have been granted to his senses and his contemplation; in fine, that the simple and most direct use of it would enable the inhabitants of the coast of the Baltic Sea to build palaces more magnificent than those of Tyre and Memphis, and to cultivate, almost under the polar circle, the most delicious fruit of the torrid zone.

Upon no branch of invention have the researches into Egyptian antiquities thrown a stronger light than upon glass-making. Thus the discovery of a glass bead, with the name of a Pharaoh of the eighteenth dynasty, proves glass-blowing to have been known upwards of 3,200 years ago. Sir Gardner Wilkinson found at Beni-Hassan two paintings of glass-blowers at work, and from the hieroglyphics accompanying them, they are shown to have been executed before the exodus of the children of Israel, 3,500 years ago. In the same age the proper proportions of the ingredients for making glass were known. Lastly, the glass bead already mentioned is of the same specific gravity as our crown-glass. This relic Captain Hervey found at Thebes, and it bears the name of a monarch 1,400 years before Christ. Such was the skill of the ancient Egyptians in glass-making that they successfully imitated the amethyst and other precious stones. Winckelmann, a high authority, is of opinion that glass was employed more frequently in ancient than in modern times. It was used by the Egyptians for coffins; they also employed it not only for drinking-vessels, but for mosaic work, the figures of deities and sacred emblems on which were of excellent workmanship and superior brilliancy of colour. Wilkinson states that the Egyptians were always celebrated for their skill in glass manufacture: "Natron, or subcarbonate of soda, a native production in different parts of the country, was the very substance most likely to lead to its invention, or rather, to its accidental discovery; and it is far more reasonable to suppose that glass would have been made where natron abounded than from a fire accidentally lighted on the sea-shore by some

Phœnicians who happened to be carrying a cargo of natron." ("The Egyptians in the Time of the Pharaohs," p. 86.)

It would be reasonable to suppose that the Hebrews brought glass and a knowledge of its manufacture out of Egypt, were not the evidence of history so explicit that it was actually discovered and wrought at their own doors.

Archimedes is stated to have constructed an orb of glass for scientific purposes. Layard found, among the ruins of Nineveh, a microscope glass, a perfect goblet, which, from the characters on it and the locality in which it was found, is believed to be of the date seven centuries before the Christian era, and is probably the most ancient piece of manufactured glass in existence.

Beads which ornament mummies are not composed of glass, but of earthenware glazed. There can, however, be but little doubt that the Egyptians were well acquainted with the materials for making glass, or rather, with the metallic oxides for colouring it; since among the tombs of Thebes have been discovered small solid pieces of glass, or a turquoise, supposed to have been used for glazing the earthenware beads and figures. Fragments of blue, white, yellow, and green glass have likewise been found—possibly made by the Greeks and Romans who conquered Egypt. The manufacture of glass was long carried on at Alexandria, from which city the Romans were supplied with that material; but before the time of Pliny the manufacture had been introduced into Italy, France, and Spain. Glass utensils have been found among the ruins of Herculaneum and Pompeii, where glass was used for windows. The Pompeian and Roman architects used glass in their mosaic decorations; such as have been found among the ruins of the villa of the Emperor Tiberius, in the island of Capri, and are to be seen on the tomb of Edward the Confessor, in Westminster Abbey. Most of the large, greenish glass cinerary vases in the British Museum, found in Roman barrows, and which contained bones and bone-ashes, are probably the production of extensive Egyptian or Roman works; the glass is somewhat impure, and is not unlike the modern common crown or sheet glass in quality. Although remains of ancient Roman potteries have been exhumed in Great Britain, it does not appear that any traces of subterranean glass-houses or works have been discovered. Strabo relates that a glass-maker of Alexandria informed him that an earth (probably manganese) was found in Egypt, without which the valuable coloured glass could not be made. It is also related that the Emperor Hadrian received, as a present from an Egyptian priest, several costly glass cups, sparkling with every colour.

During the reign of Nero, great improvements were made in Roman glass. The clear glass which bore the nearest resemblance to crystal was so highly valued, that Nero is stated to have given, for two cups of no extraordinary size, the almost incredible sum of 6,000 sestertia, or nearly £50,000. The fired glass was in such extensive use in the time of Pliny, as to have almost superseded cups of gold and silver. Hence the manufacture chiefly of vessels of glass to imitate precious stones, cut by the lathe by Roman artists, or Greek artists resident in Rome, in the style of cameos in relief. In the British Museum are preserved many fragments of vases and white opaque enamel glass, upon blue and amethyst transparent grounds, supporting the probability of the above opinion. White crystal glass, without lead, cut to imitate rock-crystal, was also then known; and a few pieces of such glass of Roman manufacture have been found, their specific gravity being only 2·049, whereas flint-glass of the usual density is about 3·200 to 1·000 of water. Subsequently, other pieces of glass were exhumed in the city of London, considered to be ancient Roman—one small piece of 2·600, and another 3·144 specific gravity. Trade secrets in the preparation of glass for gems most likely existed in ancient times; for very little has been written by Egyptian, Greek, or Roman authors on the chemical constituents of glass gems, or cameo-engraved vases. Glass in solid pieces, such as gems and mosaics, was probably manufactured in small glass-houses. The glass-makers of Rome had a street assigned to them in the first region of the city; a tax was also laid upon them by Alexander Severus, which existed in the time of Aurelius, and probably long after. This was a sort of ancient excise, which is thought to have been one of the causes that transferred the glass manufacture to Venice. Glass was employed by the Romans as an ornament in their palaces, in decorating their altars, and for a pious offering in the tombs of the dead. Many fragments have been found in the catacombs, showing it to have been used likewise by the early Christians in their places of worship. In the reign of Tiberius, a Roman artist had, according to Pliny, his home demolished for making glass malleable. This secret is stated to have been re-discovered at St. Étienne, in France, in 1845, when glass was made as malleable when cold as when first drawn from the pot; by combining silicon with other substances, it can be obtained opaque or transparent as crystal, very ductile, neither air nor acids acting upon it. Professor Schœnbein (who invented gun-cotton) made also of paper-paste window-panes, vases, bottles, etc., impermeable to water, which may be dropped on the ground without breaking, and are perfectly transparent. In a Roman villa discovered at Boxmoor, Herts, has been found a piece of window-glass of greenish hue, and about three-sixteenths of an inch in thickness; its flat under-surface, and its hammered upper-surface, show this glass to have been manufactured by pouring it in a state of fusion upon a stone slab, and flattening it by repeated blows with a mallet.

The art of manufacturing glass into such ornaments as beads and amulets was certainly known to the Druids, and glass vessels were made by the Anglo-Saxons. Near Aberfrau Palace, in Wales, have been found Druid holy snakes, used as a charm to impose upon the vulgar; they are about half as wide as our finger-rings, but much thicker, and of various colours. Roman glass, with projecting pillars on the outside, and smooth interior, have been found in London; these pillars have been formed partly by moulding, and partly by rapid rotation, increasing the projection, on the principle of centrifugal force. Other Roman specimens of this kind are to be seen in the Museum at Boulogne-sur-Mer. "English glass-makers," says Mr. Pellatt, until this discovery, "considered the *patent pillar* (as it is called) to be a modern invention. A Roman vase thus made, and a complete specimen of pillar-moulding, are to be seen entire at the Polytechnic Institution."

The Aggry beads of Ashantee were found by Mr. Bowdich in that country, but the art of making them is entirely lost. Most of these beads appear to have been coloured in their layers, afterwards twisted together in a spiral form, and then cut across; also from different coloured clays, raked together without blending. How the flowers and patterns in the body and on the surface of the rarer beads had been produced, cannot be so well explained. In 1847, there were dug up at Cuddesden, the episcopal palace of the Bishop of Oxford, two small vases, of pale blue transparent glass, the pattern being produced by thick threads of glass applied to the surface while melted; these vessels are conjectured to be of the Saxon period, fifth or sixth century. In 1846, there was found at Headington, near Oxford, an ancient bead, of deep green glass, splashed with blue and white enamel thrown down on the mass when in a soft state; it was then probably slightly twisted, and its globular form flattened. A similar bead was found in the bed of a stream near the British camp of Medmarston, and is preserved in the Ashmolean Museum, with a curious series of beads, like modern green bottle-glass, marked with white and blue enamel. Here also are curious perforated beads, of various colours; some of the enamels being formed of concentric layers, and facets cut across these producing a variety of waved lines. Another has an imitation of stones of different colours, set in studs on its surface; and a third is ornamented with raised and twisted coral work. The whole collection in form, material, colour, and design, is very fine.

The Chinese have for ages been skilled in glass-making. Remusat states that their imitation of the precious stone yecchon was so excellent that it was almost impossible to distinguish the artificial from the real. It was manufactured into vases, some clear, transparent white, extremely brilliant, and as pure as a precious stone; others of beautiful blue, and equally pure. In Egypt and Syria, no difference was known between the real and artificial yecchon, the latter being of the same form, thickness, and specific gravity as the former. It is even asserted that at Cairo, and other cities, the artificial yecchon vases were as highly valued as the real. The Chinese have equally well imitated their ju-stone; it is coloured greenish, and of such hardness and weight that it frequently surpasses the real ju: fragments of it are erroneously denominated rice composition. A specimen of the artificial ju may be seen in the British Museum.

PRACTICAL PERSPECTIVE.—XV.

THE subject of the present study is introduced in order to show that so long as the plane of a circle or semicircle remains parallel to the picture-plane the form is not in any way altered, but is merely described with a shorter radius, varying according to the distance of the object from the picture.

Having drawn the front elevation of the two piers (Fig. 74), join them by the line D E, and from the centre C′ describe the semi-circular arch; produce the external lines of the piers, and draw the top line of the elevation.

Now from A and A′, *a a′*, D and E, draw lines to the centre of the picture, C.

From A set off A B equal to the real depth of the arch, and from B draw a line to the point of distance (not shown in this figure), cutting the line drawn from A to the centre of the picture in B′.

Through B′ draw a horizontal line, cutting the line drawn from A′ in B″, and cutting also those drawn from *a a′* in *b* and *b′*.

The lines *b* B′ and B″ *b′* will represent the bottom lines of the other side of the piers, corresponding with *a* A and A′-*a′* of the front elevation.

EXERCISE 78.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 14 feet.

There is a block of stone 5 feet square and 1 foot thick; there is a circular hole of 1½ foot radius pierced through the middle of it. Give a perspective view of this object when standing so that its square surface is parallel to the plane of the picture, at 3 feet on the right of the spectator.

EXERCISE 79.

Give in the same picture a view of the object when standing at 8 feet on the left of the spectator, and 6 feet within the picture.

EXERCISE 80.

Put into perspective the same object when lying on its square surface, so that one of the edges of the plan coincides with the picture-line, its situation being 6 feet on the left of the spectator.

EXERCISE 81.

Give a perspective view of the object when lying on its square surface at 7 feet on the right of the spectator, and 8 feet within the picture, its front and back edges being parallel to the plane of the picture.

In the next study an application of the projection is shown in the delineation of a viaduct.

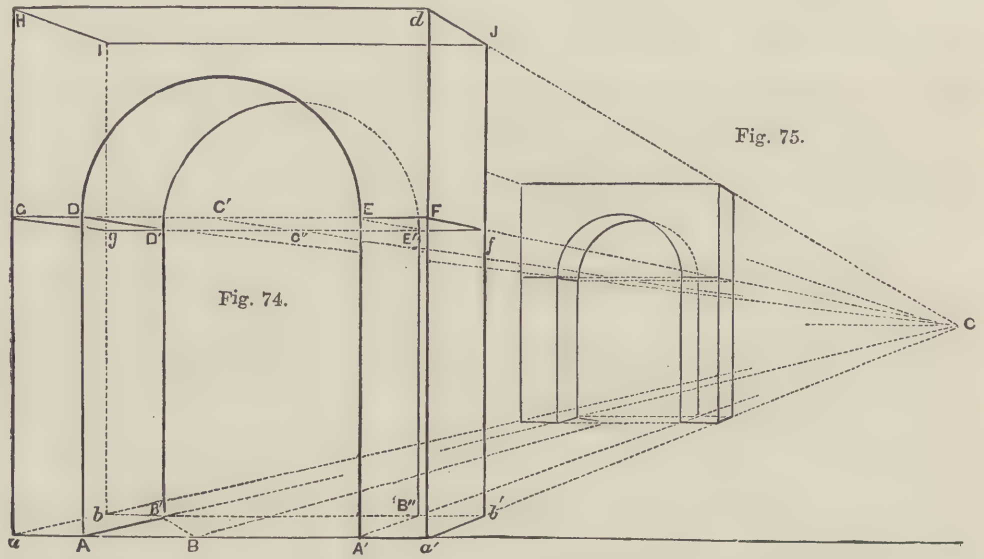


Fig. 74.

Fig. 75.

A perpendicular drawn from *b′* to meet a line drawn to the centre of the picture from *d* in the point J will complete the distant side of the object.

A perpendicular drawn from B′ to meet the line drawn to the centre of the picture from D will give the point D′, the springing of the arch of the back elevation.

Now from E draw a line to the centre of the picture, and from B″ draw a perpendicular, cutting the line drawn from E in E′, the second springing point of the arch in the back elevation.

Draw the springing line, D′ E′; then, if all the previous steps have been accurately followed, D′ E′ produced should meet a line drawn from F to the centre in *f*—that is, in the point where the line drawn from F cuts the perpendicular *b′*; and, similarly, it should cut a line drawn from G in *g*, the point where the line G intersects the perpendicular *b*. The perpendicular *b* should also, when produced, meet a line drawn from H to the centre of the picture in I, the point at which H is cut by a horizontal from J.

It now only remains to draw the distant semicircle.

From C′, the centre of the arch in the front elevation, draw a line to the centre of the picture, cutting the springing line D′ E′ in C″, which point is the centre required.

From C″, with radius C″ E′ or C″ D′ draw the arch, the part which would be hidden being drawn in either a finer line than the rest, or in dots.

Fig. 75 shows the same object when at a distance within the picture.

The student will not find any difficulty in projecting the whole block, or the piers, and therefore, although all the working lines are given, it is not deemed necessary to give any instruction on that portion of the study, and we therefore proceed at once to the arches.

Fig. 76 is the geometrical elevation of the arch enclosed in the parallelogram A B C D. As the arch is a semicircle, this parallelogram will, of course, be half a square, the lines B G and C G will be the semi-diagonals, and the line G H the half-diameter, or height of the arch from the springing.

It will, of course, be evident that the lines A B and C D of Fig. 76 will in Fig. 77 be portions of the inner edges of the piers; therefore,

Having produced the nearest perpendicular, K, until it reaches L, the complete height of the structure, mark on it above A′ (the top of the first pier) the height A′ B′, and from B′ draw a line to the centre of the picture, cutting the inner edges of the piers M and N in B and C.

The intersections A and D will already exist, as the line from A′ to the centre of the picture will have been drawn when projecting the piers.

The figure A B C D will then be the perspective projection of the containing rectangle.

Now, between the points on the picture-line which mark the real span of the arches, mark off the centre E, and from it draw a line to the point of distance, cutting the line drawn from K to the centre of the picture in F.

From F draw a perpendicular, which, cutting A D in G, will give the perspective centre, and cutting B C in H, will give the crown of the arch.

From B′ and A′ draw lines across the side of the first pier to b' and a', and from these draw lines to the centre of the picture.

Perpendiculars from m and n will cut these lines in a b c and

From I and J draw horizontals, cutting the semi-diagonals $b\ g$ and $c\ g$ in i and j. Now, starting from A, trace the curve of the arch, passing through I H J to D; also the corresponding curve, passing from a through $i\ h\ j$ to d, the hidden portion being drawn either in dots or a fine line, whilst the part which is visible at $d\ j$ is to be fully drawn.

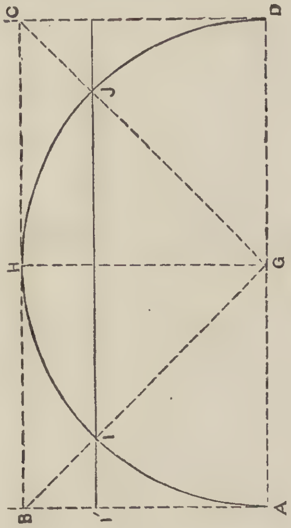


Fig. 76.

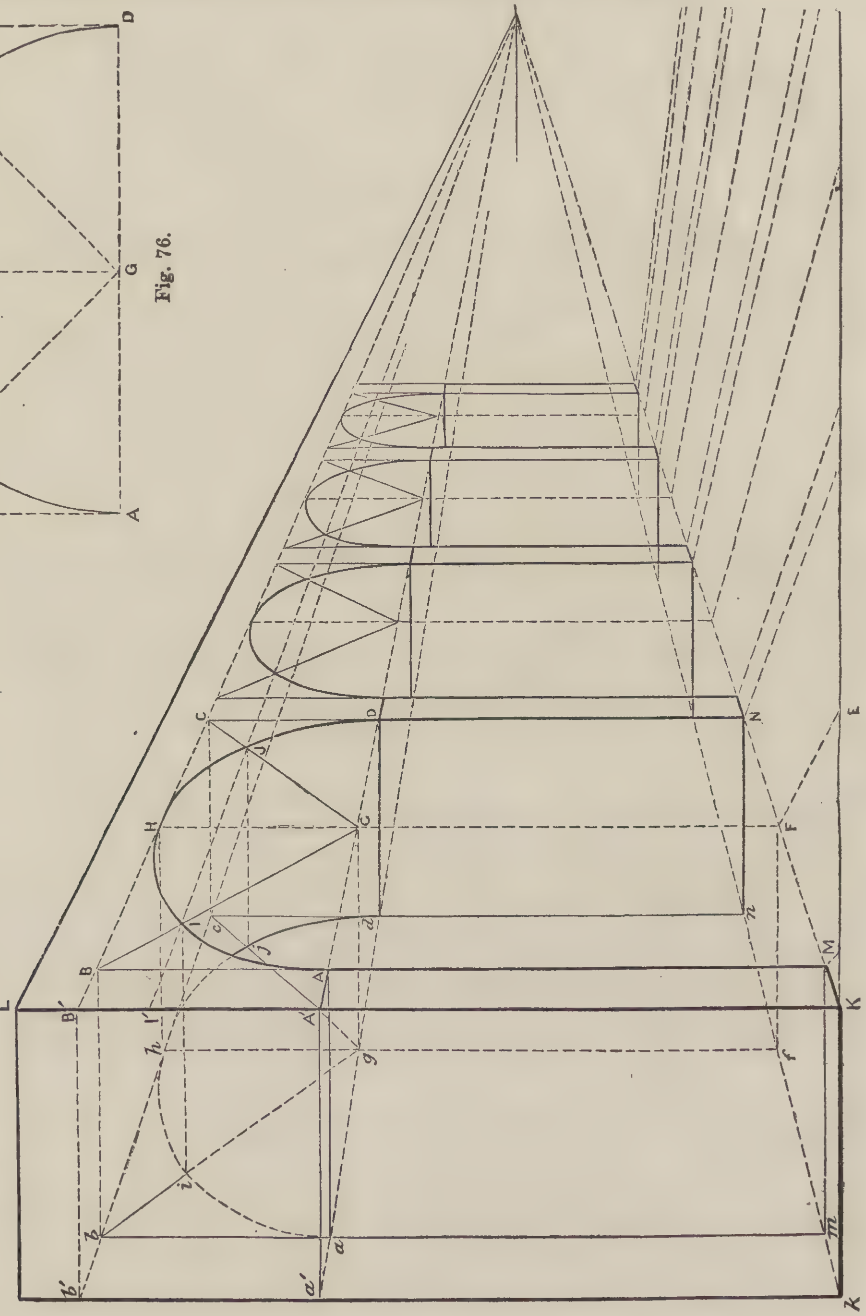


Fig. 77.

d, which will be the projection of the containing rectangle on the opposite elevations.

From F draw a horizontal line to f, and on f erect a perpendicular, cutting $a'\ d$ in g, and cutting $b'\ c$ in h.

Then g will be the centre, and h the crown of the arch, of the distant elevation.

Now draw the semi-diagonals B G and C G, and also $b\ g$ and $c\ g$.

From A′ set off A I′, and from I′ draw a line to the centre of the picture, cutting the diagonals in I and J.

This process is to be repeated for each arch, but the work will be materially lessened after the first has been drawn, as several of the lines already used will be available for all; and, further, as the arches recede, those on the opposite elevation will become invisible, and it will therefore be unnecessary to draw them, excepting for special study.

Exercise 82.

Put into perspective the series of arches similar to those shown in

Figs. 74, 75, when the front elevation is placed at 50° to the plane of projection. The scale, height of spectator, distance, and dimensions at pleasure.

The limits of these lessons preclude our carrying this subject any further; but the student is urged to remember that this series of lessons is merely elementary, and that it is want of space, and not want of matter, which compels us to close. Each lesson herein given, however, is capable of further working out, and it is hoped that every learner will endeavour to vary and apply the studies so as to acquire a thorough knowledge of the subject as far as taught in these pages, and he will thus prepare himself for the advanced courses specially adapted to the various branches of industry which will diverge from this.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XVII.—JOHN ROEBUCK, M.D., F.R.S.

BY JAMES GRANT.

Dr. John Roebuck, one of England's greatest experimentists in metallurgy and chemistry, and who, had he fully succeeded as projector of the great Carron Ironworks, would have been deemed one of Scotland's greatest benefactors—"one who, during a long and active life, was distinguished by uncommon talents and great virtues"—was born in 1718, at Sheffield, where his father carried on the business of cutler, in the course of which he realised a comfortable competency. Pleased with his success in life, he wished his son to follow his own trade, but the lad being irresistibly attracted to something higher than mere dealing in hardwares, and having a love for science, was liberally encouraged in his tastes by his father. He was thus sent to Northampton, and placed under the tutelage of the Rev. Philip Doddridge, who there taught classical literature, logic, ethics, theology, and some collateral branches, and who had then among his pupils Hugh Farmer, afterwards known by his writings. Dr. Aikin, the father of Mrs. Barbauld, was one of his assistants, and his lectures were attended by students even from Scotland and Holland. From this provincial seminary he was sent to the University of Edinburgh, where he applied himself to the study of medicine, but more particularly that of chemistry, which was then the subject of much attention at all the Scottish universities. While in Edinburgh he contracted many friendships (which were useful to him in after life) among the men of letters for whom the North was then famous, particularly Hume and Robertson, the historians; and "this circumstance is supposed to have contributed not a little to his partiality in favour of Scotland, and his afterwards selecting it as the field for his industrial operations."

After studying and graduating at Leyden, in 1745 he settled at Birmingham, which then consisted of little more than thirty small streets; but it was in that year that Boulton's invention for inlaid steel for buckles, watch-chains, and other articles was there brought to perfection; and, even then, Birmingham was the principal seat of the metal manufacture, and its mechanics were deemed among the most skilful in Britain. While practising his profession, the attention of Dr. Roebuck was drawn at an early period to the extreme scarcity and high price of the material in which the tradesmen worked, and he conceived that a method might be devised to smelt the iron otherwise than by charcoal. He had a laboratory fitted up in his house for the purpose of prosecuting inquiries with this end in view, and at the crucible he spent every hour he had to spare from his professional duties. It was thus that, like Dudd Dudley in the preceding century, he came upon the same process of smelting iron by pit-coal, and afterwards had it embodied, like that luckless cavalier-projector, in a patent. He invented also new and improved modes of refining gold and silver; and these proved of vast practical value to the mechanics of Birmingham in their various branches of trade.

Roebuck next sought to invent the most economical modes of procuring the different chemical forces, such as ammonia, sublimate, and other acids, used in the Birmingham trade; and so great was his success in these efforts that he was induced to build a large laboratory for their manufacture, and this his friend Mr. Garbett conducted with great skill. His success led him to project the establishment of a large manufactory for the modern process of distilling vitriolic acid in larger quantities, and in leaden in lieu of glass vessels; and having now relinquished his practice of physic, and taken as a partner Mr. Garbett, he resolved to establish his new works in Scotland, and with this view repaired to Prestonpans, a melancholy old burgh then and now, hastening to ruin, situated somewhat bleakly, on the south bank of the Forth. There, in 1749, he built his projected works, and the enterprise proved so successful and lucrative that he resolved to strike out new branches, and started a pottery, which exists to this day, in the same neighbourhood, for the manufacture of white and brown earthenware. The clay used in this work was brought from Devonshire; the flint from Kent; the red and white lead from London and Hull.

About this time he had the good fortune to make the friendship of Mr. Cadell, of Cockenzie, a neighbouring proprietor, who was earnestly intent on developing the industries of Scotland, which were then in a very backward condition, and for long after were crushed by centralisation and imperial neglect. Cadell had frequently endeavoured, without success, to establish a manufactory of iron; but, on being joined by Roebuck, they proposed to organise a company, select a site, and make the necessary arrangements for beginning the smelting of iron. A careful examination of the coasts of Fife and Lothian led Roebuck to select a spot on the then sequestered banks of the Carron, near Larbert, in Stirlingshire, where there was a plentiful flow of water, and in the neighbourhood an inexhaustible supply of iron, coal, and limestone; and there, on that ground which Scottish history and tradition alike have made classic, Dr. Roebuck planted the first Scottish ironworks, and there the first furnace was blown on January 1st, 1760.

Skilled workmen, who were brought from England by Roebuck, formed the nucleus of industry there; and in the course of the first year the works turned out 1,500 tons of iron. The original capital was £150,000, divided into 600 shares; and by the year 1772, 2,000 men were employed there. The operations carried on within were long kept a secret from the outer world, and hence the rule which excluded Robert Burns when he went to view the place—a rule which still exists to a great extent. In accordance with his patent, dated 1762, the doctor used pit-coal, and thus describes his process:—

"I melt pig or any kind of cast-iron in a hearth heated with pit-coal by the blast of bellows, and work the metal until it is reduced to nature, which I take out of the fire and separate to pieces; then I take the metal thus reduced, and expose it to the action of a hollow pit-coal fire, heated by the blast of bellows, till it is reduced to a loop, which I draw out under a common forge hammer into bar-iron."

The principal production of the Carron Works was castings, for which the peculiar quality of the Scotch iron admirably adapts it.

In 1771 the projector had the misfortune to lose his brother, Mr. Ebenezer Roebuck, a merchant of London, and partner in the company, who, while viewing the Carron Works, was crushed to death by a vast piece of iron which fell upon him.

The ship and battery guns so long and well known as carronades or "smashers" were first cast here in 1779—the invention of General Robert Melville, an officer who served under Lord Rollo at the capture of Dominica, the storming of Martinique, and elsewhere. They were peculiarly constructed, being shorter and lighter than other cannon, and having a chamber for the powder, like a mortar. They were cast in enormous numbers at Carron, and were employed throughout all the fighting and mercantile marine of Europe and of America. The first of them was presented by the Carron Company to the family of the general, who still preserve it; and an inscription on the carriage records that they were cast for "solid, ship, shell, or carcass shot, and first used against the French fleet in 1779."

Wealth was now flowing in for a time upon Dr. Roebuck, who embarked in coal-mining, and became the lessee of the Duke of Hamilton's great mines at Borrowstowness, as well as the salt-pans in connection with them. He then, with his family, leased one of the duke's country-seats, named Kinniel, a stately old chateau, situated on the edge of a beautiful bank fifty feet above the Forth, surrounded by gardens and great old trees, and commanding a fine view of the whole estuary and coast of Fife.

In sinking for coal at the new mines, he found a necessity for pumping machinery of the most powerful kind to keep them

clear of water; and Newcomen's engine being found insufficient for that purpose, his friend, Professor Joseph Black, who then occupied the chair of chemistry at Edinburgh, and is celebrated as the discoverer of fixed air or *carbonic gas*, informed him "of a young man of his acquaintance, a mathematical instrument maker in Glasgow, who had invented a steam-engine calculated to work with greatly increased power, speed, and economy, compared with Newcomen's." Roebuck was much interested on hearing this, and immediately wrote to "the young man" in question, who proved to be no other than James Watt! He was invited to Kinniel, whither he came in the month of May, 1768, and Roebuck was so pleased with his engine and mechanical genius, that the subjects of its introduction to general use, and of his becoming a partner, were speedily discussed. Watt, who, as we have related in his memoir, had been labouring at his invention for years, contending with the difficulties incident to limited means, and was deeply indebted to Professor Black, whose monetary advances "he had felt to hang like a millstone about his neck," hailed with pleasure the patronage of Roebuck—one accustomed to great enterprises, "a bold and undaunted man, and disregardful of expense when he saw before him a reasonable prospect of success. His reputation as a practical chemist and philosopher, and his success as the founder of the Prestonpans Chemical Works and of the Carron Iron Works, justified the friends of Watt in thinking that he was, of all men, the best calculated to help him at this juncture, and hence they sought to bring about a more intimate connection between the two. The result was that Dr. Roebuck eventually became a partner to the extent of two-thirds of the invention, took upon him the debt owing by Watt to Professor Black, about £1,200, and undertook to find the requisite money to protect the invention by patent. The necessary steps were taken accordingly, and the patent right was secured by the beginning of 1769, though the perfecting of his model cost Watt much further anxiety and study."

It was in an outhouse, still standing at Kinniel, and close behind the old ducal mansion, by the burnside in a wooded glen, that Watt worked till he brought his engine to perfection, and his somewhat desponding spirit was always cheered the while by the hopeful nature of Roebuck.

In the course of his useful and public-spirited exertions, the latter met with many pleasing and flattering marks of approbation from the most distinguished men in the country; and the magistrates of Edinburgh, when he was presented publicly with the freedom of the city, stated "that they granted it to him for the eminent services he had done to Scotland." The Carron Works still employ more than 2,000 men; there are five blast or smelting furnaces, four cupola furnaces, and twenty air furnaces. Besides the machinery driven by water, there is a steam-engine of 90-horse power, which is used entirely in the production of blast. All kinds of cast-iron goods are manufactured there—cannon, mortars, carronades, shot, shell, agricultural implements, pipes, boilers, ovens, vats, pots, etc.

When Roebuck's speculations were at their zenith, misfortunes began to come upon him; and when the fatal crash came, *he* sank under the burthen, and not Watt. The progress of the latter's engine was slow, and as it was long before it could be applied to draining the mines, the heavy responsibilities of Roebuck were proving too much for him. The opening out of the principal coal involved an enormous outlay; it had extended over years, during which the bold English speculator sunk not only his own fortune, but that of his wife, and large sums borrowed from many friends—a resort that distressed him deeply—all of which he was eventually totally unable to repay or to retrieve. Yet he struggled hard and nobly. From his refining works at Birmingham and his vitriol works at Prestonpans he withdrew his entire capital; while at the same time he transferred to Watt his entire interest in the steam-engine, "the value of which was thought so small that it was not even included among the assets; Roebuck's creditors not estimating it as worth one farthing!"

Roebuck did not long survive his pecuniary misfortunes; after a little time spent in comparative obscurity, he died at Kinniel House, July 16th, 1794, in his seventy-sixth year. From Kinniel, according to the *Scottish Chronicle*, "he was carried to the place of interment in the churchyard of Carriden, on the 19th, amid the silent and respectful sorrow of many hundreds of his workmen and their families."

Such was the energetic career of one whom a Cyclopædia of Biography dismisses thus with two pithy lines:—

"Roebuck, John, a physician and experimental chemist, born at Sheffield in 1718; died, after ruining himself by his projects, 1794."

By a chance in the turn of events, his native town of Sheffield is represented in the British Parliament by John Arthur Roebuck, his grandson.

PRACTICAL APPLICATION OF THE FINE ARTS.—IV.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

CUTTING OUT, SHADING, AND BURNING THE GLASS.

Matching Colours.—We have spoken of the manufacture of pot metal; the next process is to prepare this pot metal for the picture. The first thing necessary is to make choice of the glass to be used, and for this purpose it is convenient to have a frame fixed with small pieces of glass of various colours and different manufactures; and this frame hung before a window with a good light, looking to the north, and not obstructed by houses or trees, but so placed that the glass can be seen against the clear sky, gives an opportunity of matching the colours with those of the original design. In this matching the colours it must be remembered that the plain glass should approach most nearly to the tint of the brightest part of each colour, as the subsequent shades will make the colour darker and somewhat duller; though the aim of good painting is to avoid as much as possible dulling the original colour. But whatever care may be taken to match the glass by specimen pieces, after all the actual sheets of pot-metal must be taken out and examined to choose those sheets which, from their thickness, depth of colour, imperfections, and shading of tint, are suitable to the subject in hand.

Cutting out.—The glass being chosen, it is laid upon the working drawing or cartoon, and with a diamond cut to the required shape. The ancients, who did not use diamonds (and we do not know that the use of the diamond was discovered before the time of Queen Elizabeth and Francis I., and it was not commonly employed in cutting until 1700, though perhaps some scratching had been done at an earlier period), had to adopt other methods, and elaborate directions are given in old treatises how the glass might be divided. From this imperfection of instruments we may explain some of the more frequent leadings which we find in a great many of the old windows; though, no doubt, much more is to be accounted for by mending subsequent upon cracking. The English plan of having a charcoal drawing upon white paper is preferable at this stage to the French habit of drawing on a blue paper; since the black lines on the white are clearly visible through the semi-transparent glass, whereas the drawing on a blue paper has to be traced on the glass before the latter is cut.

When the glass is cut into a proper shape it is roughly clamped together with bits of leading or lumps of cobbler's-wax, and hung up, so as to represent the intended picture in general outline.

Painting.—The shading now begins. This is effected by a process of enamelling; that is, the surface of the glass is rendered less transparent by the use of metallic oxides. What is technically called *staining* is an entirely different process, though apparently the means are the same. Staining implies the imparting a yellow, orange, or similar colour through the depth of the glass without detracting from the transparency. The enamelling is burning into the surface of the glass a metal which, while it imparts some colour, at the same time destroys more or less completely the transparency of the material. The great art in painting or enamelling is to overcome this difficulty of destroying the transparency, as may especially be seen, either in those miserable failures of foreign workmanship in St. Paul's Cathedral or at Glasgow; for with glass of even greater transparency than the English the Continental glass-painters contrive to make opaque pictures instead of transparencies. It was against this that the late Mr. Winston so earnestly warned modern glass-painters.

Materials.—The materials used in enamelling are principally oxides of iron, both red and black; and with these are used sometimes red or white lead, the whole being mixed with silica

and borax. The various materials used give a variety of colour to the shade, and judgment must be used to adapt the tone to the result required. The materials can probably be best obtained from some glass-painter, until the artist becomes a little accustomed to the use of them. They are mixed with various vehicles, either water or oil. If water is employed, a little gum should be added to stiffen the pigment. The oils used are turpentine, oil of lavender, oil of thyme, and tar. It is usual to use water in the earlier process, and to finish off with oil. The implements used are given in Fig. 2. They consist of one or two flat sables, No. 4; a stippler made of hog's hair, No. 1; a tracer of sable, No. 2; a scrubb, Nos. 3 and 5, made of hog's hair cut down from an ordinary oil-colour tool, either round or flat, the latter being better; and a shader for oil colour. This last may be either sable or camel's hair.

Kinds of Shading.—The various kinds of shading are called (1) the smudge or smear, (2) stippling, and (3) line-shading. The whole of these three kinds of shading are frequently used in the same window. 1. The smear is applied with a large soft brush, No. 4; of course, not flat all over alike, but deepest in those portions where the shadow is to be darkest; but this is much improved if it is stippled with such a brush as No. 1. This is done by pushing the end of the hairs against the glass and withdrawing the tool quickly. By this means the pigment, instead of lying in flat sheets or in streaky lines, is drawn up into dots and short strokes, leaving interstices through which the light can penetrate. When this first shading is dry it will be possible to rub off the pigment, which has become powdery, from those parts that should be quite light. This may be done either with such a brush as Nos. 3 or 5, or with the handle of the brush or other convenient stick. After this it will be useful to apply more shade, and this is usually mixed with an oil vehicle, either as before with stippling, or by tracing lines of some considerable force with brush No. 2. When the outlines are strongly marked it will frequently be found convenient to trace out these first with No. 2, and afterwards to add the stippling when the former is dry. The early painters of the twelfth century not unfrequently rested entirely upon the force of their line-shading, and seldom used stippling. In the case of stippling or smear-shading with an oil vehicle it will be found advantageous to lay on a thin coating of oil or two previously, in order to make the colour work more easily.

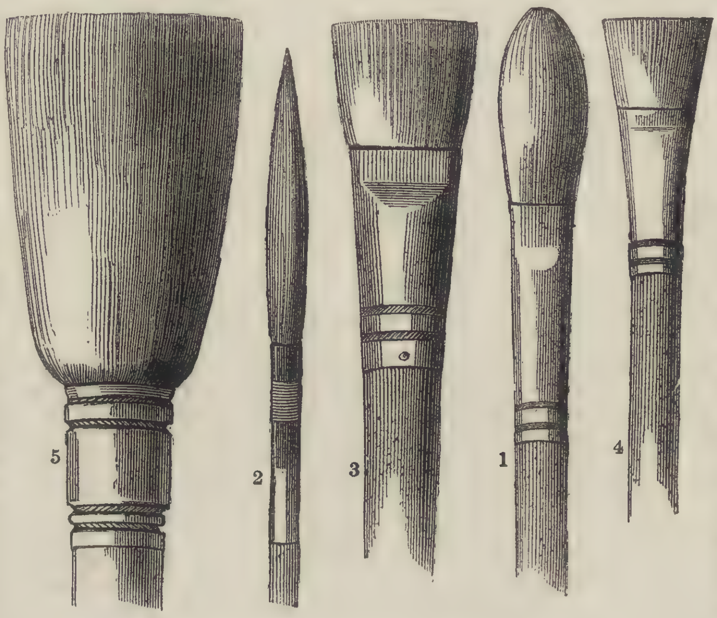


Fig. 2.—BRUSHES USED IN GLASS-PAINTING.

Practice in chalk-drawing will assist the artist towards a mastery of the character of shading required for glass-painting. The general shades put in with the stump answer to the smear and stippling, whilst the firm black lines added afterwards correspond with the shades produced with the small fine brush.

With the *flashed* glasses, which are almost all of a ruby colour, with either white (*i.e.*, transparent), or light brown, or yellow foundation, another treatment is sometimes adopted; the flashing is removed either with fluoric acid or by grinding—in glass-painting almost always by the former process. The plain glass thus left can again be stained with nitrate of silver, or shaded like other glass.

Effects of Shading on Different Coloured Glasses.—It will soon be found that different coloured glasses receive the shading differently. Delicacy of shadow and half-tints would be entirely lost upon deep and heavy glass; whereas on flesh tints, white glass, and other pale tints, great variety and delicacy can be used. The shading, again, after it is burnt seldom appears so deep as it did when the unburnt pigment lay on the surface; but in this respect there is considerable difference in different glasses.

Grisaille.—In the above we have entered into all the processes of staining and shading every kind of glass; but the beginner will find that the sort of glass-painting called grisaille will afford him considerable scope for the employment of his talents, and yet not be so complicated as where a great variety of colours are combined. This consists of brown patterns or scroll-work, accompanied by yellow stain upon white glass.

Burning.—The glass being thus painted, it is ready for burning, and this is accomplished in furnaces fitted with shelves or drawers of iron, covered with lime finely powdered. On this lime the glass is placed, and the whole subjected to considerable heat, but not sufficient to melt the glass, only enough to soften it. During this process the silver sinks through the plates of glass, whilst the shade is attached to the surface so finely that it cannot be detached. Either through defective burning or from the chemical action of various gases upon the surface of the glass, the shade will not unfrequently come off old glass if only scratched with the nail. A good deal of care and watchfulness is required to heat the glass to the required temperature so as not to melt it on the one hand, and on the other to ensure the fixture of the colour.

The glass may be burnt several times over, but it is better, if possible, to arrive at the desired effect in one burning, for not only does this save time—a matter which should always be a consideration with the "cunning workman"—but it imparts a greater transparency and brightness to the glass.

Leading.—The glass being now completed, it is all ready to be fastened together with the leads. These leads are in something of the form of an H placed sideways, thus ⌶. The workman takes a piece of the glass, and cuts off a portion long enough to go completely round it. He then bends it round the corners, and presses in the lips of the folds. When it is fitted, the chinks between the lead and the glass are filled up with putty or cement, and the joints are soldered together. Care is taken to fix little wire hooks to such parts of the leading as will come against the stanchions, and the whole is completed and fit to be raised to its appointed place.

The Proper Study of Antiquity.—In this matter of leading, as in almost all other points connected with painted glass, the work of the ancients and of the moderns should be observed; the former with a view of imitating the different modes by which various difficulties should be overcome, at the same time avoiding the peculiarities which their ignorance of many modern inventions made compulsory; the latter, that their deficiencies, carelessnesses, and want of taste may become a warning of shoals and rocks upon which the competition and aim at cheapness of modern times have shipwrecked many an intelligent workman and many a painstaking artist. The leads of the ancients were narrow but strong, scarcely perceptible in the pictures; whereas those of the last and the early part of the present century were broad and disfigured the glass. The present manufacturers, in this respect as in many others, are doing their best to cultivate a wise and discriminating imitation of antiquity.

THE STEAM-ENGINE.—XII.

By J. M. Wigner, B.A.

THE LOCOMOTIVE — SPECIAL REQUIREMENTS — FURNACE — TUBULAR BOILER — MECHANISM — REVERSING GEAR — GOODS ENGINES.

We have reserved for this our concluding paper a description of the locomotive, which is one of the most important applications of the power of steam. In modern times the whole of this and several other countries has been intersected by various lines of railway, and there are scarcely any countries entirely devoid of them. In many places, indeed, they have performed a very important office, having served as the pioneers of civilisation, and opened up fresh fields for industry and commerce.

In India their influence in this way has been much felt, and hence the system there is at the present time being greatly extended.

This rapid development of the railway system has very naturally directed much attention towards the best and most economical form of steam-engine suitable for working it. The plan of employing a fixed winding-engine with a long rope attached to the carriages was soon found to be costly and unsatisfactory, and at the present time locomotives of various kinds are employed on all passenger lines, the old plan being still retained on a few mineral lines with steep gradients.

On all long and important lines there are two perfectly distinct kinds of traffic, the one consisting of passengers and parcels of light weight, the other of heavy goods and parcels. For the former of these the greatest rate of speed that can safely be attained is desirable, and passenger engines are accordingly constructed capable of drawing light loads at a speed of at least 50 or 60 miles per hour. For the goods traffic engines of a much more powerful form are constructed; these possess greatly increased tractive power, but travel at a slower pace than passenger engines. On some of the Continental railways, goods engines of a very cumbrous and complicated construction have of late been introduced, some of them possessing as many as six pairs of driving-wheels, and four cylinders. It seems probable, however, that the same duty might be more efficiently and economically performed by the employment of two ordinary goods engines coupled together, when such very heavy trains are required.

There are many things which have to be considered in the construction of a locomotive. Its various parts must be made very strong and securely fastened together, to enable it to resist the constant vibration arising from the rapid motion. The boiler is also limited in diameter by the distance between the wheels, as it is very inconvenient for it to overhang them; and its dimensions being thus limited, various arrangements have to be made to enable a sufficient amount of steam to be generated.

The engine has also to be so constructed as to carry with it a supply of fuel and water sufficient to last it for the journey, or till it arrives at some station where it can be replenished. In engines which run on the long lines of railway a separate tender is usually provided to hold these, and is coupled closely behind the engine. In those, however, which run short distances—as, for instance, on many of the metropolitan lines—the tender is dispensed with, a small tank and coal bunker being arranged at the hinder part of the engine.

Considerable arrangement is requisite to ensure the due distribution of the weight on the various wheels: the greater portion should rest on those which drive the engine, as they thus obtain a much firmer grip on the rails. Great fears were at first entertained lest this grip should prove insufficient to propel a heavy train, but experience has now completely dissipated these. In frosty weather there is occasionally a difficulty at starting, but a little sand or gravel scattered on the rails soon overcomes this, and in most engines a small sand-box with a shoot is now placed at the side so as to scatter a little sand in this way when necessary.

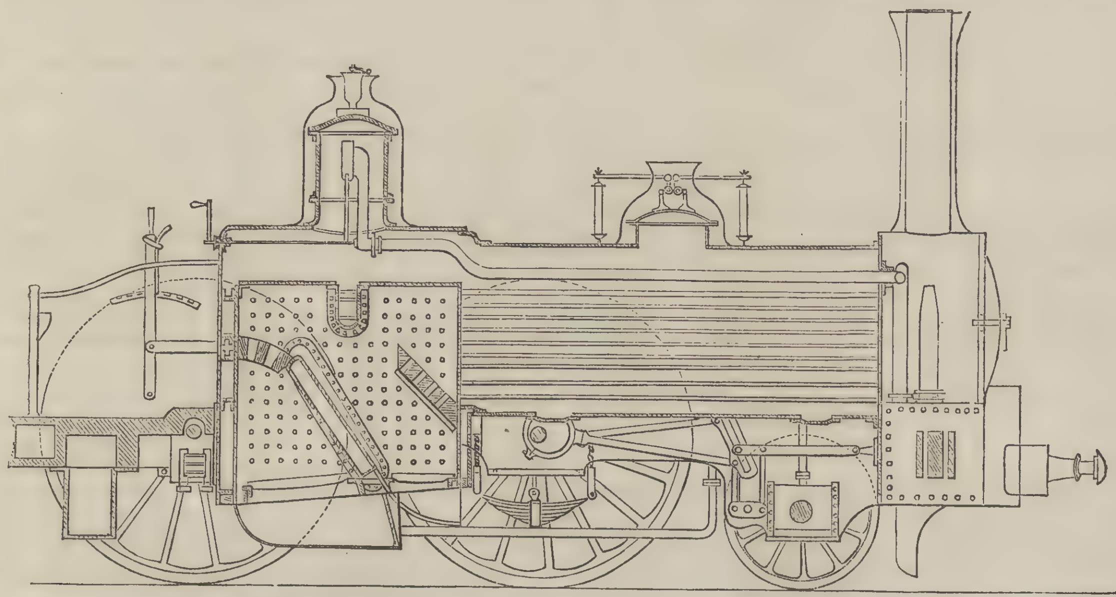


Fig. 45.—SECTION OF EXPRESS PASSENGER LOCOMOTIVE ENGINE.

The great object that has been aimed at of late is to construct a locomotive which shall burn coal, and at the same time consume its own smoke. All engines are now required by law to burn coke in order to avoid the injurious effects of the smoke, but this adds greatly to the expense, coke being much less economical than coal as a source of heat.

In Cudworth's engine the furnace is made very long and sloping, and only a thin layer of fuel is laid upon it. The coal is then gradually supplied in front, and the smoke is mainly consumed as it travels over the incandescent fuel beyond and becomes mingled with the air that enters through the fire-door.

Other engines are fitted with a combustion-chamber beyond the furnace, and in this the flame and gases become mixed with air and consumed. In Beattie's form there are two furnaces so arranged that the products of combustion in the lower shall pass over the other, and thus be consumed before they reach the flues. In this case the upper furnace is fed with coke, while the lower may be fed with coals, as the smoke given off from it is consumed in passing over the coke fire.

Very many other plans have been tried with varying degrees of success, but none can yet be said to have fully attained the

desired end, though the amount of smoke evolved is materially diminished by their adoption.

The general construction of the locomotive will be best understood by means of a sectional view. We have accordingly given one of an express passenger-engine with coupled driving-wheels, similar to many in use on the London and North-Western line at the present time, and we shall proceed to explain in succession the details of the various parts (Fig. 45). The furnace here shown is constructed on Beattie's plan, being divided into two portions by a sloping water-bridge which passes from side to side of the furnace. The smoke from the lower or hinder furnace passes through perforations in this bridge, and in the fire-block against which it leans, into the second furnace. A hanging bridge at the top of this deflects the smoke downwards on the burning coke, and thus ensures its being consumed, while a second perforated bridge placed at the back of the fire-box prevents the heated gases escaping too rapidly into the flues. The sides of the fire-box are made double, the water in the boiler being allowed to circulate in the space between the two plates, and much heat is thus imparted to it. Various stays connect these two plates together so as to prevent their bulging, and some of these stays are made hollow so as to increase the heating surface of the fire-box.

Movable ash-trays are placed under each of the furnaces to receive the hot cinders that fall from them, and levers are usually provided by which the doors of these ash-pans may be opened, and the cinders allowed to escape.

The barrel of the boiler below the water-line is occupied by a large number of tubes, usually made of brass, and securely fastened to the back of the fire-box, and in front to a plate fixed in the end of the boiler. The smoke as it passes through these imparts to the water the greater portion of its heat, and then escapes into the "smoke-box," as the front portion of the engine directly under the chimney is called. The tubes are of small diameter, usually about $1\frac{3}{4}$ or 2 inches, and are placed as close as they well can be, when sufficient room is left for the circulation of the water between them.

In the front of the engine is a door which opens into the smoke-box; sometimes this is made in one piece, and can be removed entirely, being held in its place by a screwed bolt and nuts; at other times it is made in two pieces hinged at each side. By opening this, access is gained to the smoke-box for the purpose of removing soot or ashes which may be deposited there, and also to clean out the tubes.

The funnel of a locomotive must of necessity be somewhat short, to admit of its passing under the various bridges which so often cross a line of railway. This fact, coupled with the small diameter of the tubes, tends to render the draught somewhat feeble, and hence there was at first difficulty in maintaining sufficiently rapid combustion in the furnace. This is entirely overcome by allowing the exhaust steam to escape into the chimney. The two exhausts are connected by a Y, or, as it is termed, a breeches-pipe, to one mouthpiece; and the constant escape of the steam at a considerable pressure from this quickens the draught very greatly, and produces the snorting or puffing so well known to all who have observed an engine at work. This jet is usually carried a little higher than the mouth of the uppermost layer of tubes.

On the top of the engine are seen two domes. The front and smaller one of these is fitted with two safety-valves, one of which is usually secured so that it cannot be altered by the engineer. A valve is also frequently fitted at the top of the other dome, but the main purpose of this is for the mouth of the steam-pipe to open in it. The higher this can be made to open above the surface of the water in the boiler the better it is, as the ebullition, added to the shaking of the engine, keeps a larger amount of water mechanically suspended in the steam space, in a state of minute division. If much of this were allowed to enter the steam-pipe, there would be an excessive amount of priming. As it is, the blow-off cocks in the cylinder have to be frequently opened to allow of the escape of the condensed water.

The mouth of the steam-pipe is therefore situated near the top of the dome, and is closed by a valve which is regulated by the handle seen over the furnace-door. Sometimes a valve of ordinary construction is used for this purpose, but more frequently there are a number of parallel slots at the mouth of the pipe, and against these a gridiron plate, cut with corresponding slots, works steam-tight. The degree to which the valve is opened is capable of exact adjustment by means of the handle, the motion being usually communicated by means of an eccentric fixed on the rod, and thus the engineer can increase or diminish at pleasure the supply of steam to the cylinder.

The steam-pipe passes along inside the boiler, and through the end of it by a steam-tight joint into the smoke-box, where it divides into two branches, one of which goes to each cylinder.

The cylinders are situated at the lower part of the smoke-box, often being included within it. In the engine figured their diameter is about 17 inches, and the stroke nearly 2 feet. The head of the piston-rod is made to work between guides firmly secured to the frame-work of the engine, and a connecting-rod passes from this head to a crank which is forged on the axle of the driving-wheels. A straight connecting-rod also passes from a crank fixed to the end of this axle outside the wheel to a similar crank fixed to the axle of the hinder pair of wheels, so that there are four driving-wheels instead of two, and in this way a much greater hold on the rails is obtained. These wheels must, of course, have exactly the same diameter, and the cranks on their axes must be similarly placed. In the engine shown their diameter is 7 feet, and they are about 5 inches in width; a few are made even larger than this, but the usual size in ordinary passenger engines is from 5 to 6 feet. A small flange is turned on the inner edge of all the wheels to keep them from running off the rails.

The connecting-rods and guides are not shown in the figure, as they would only render it more complicated.

We come now to a very important point, namely, the slide-valve, and the means of controlling its movements in such a way as to make the engine travel forwards or backwards at pleasure. The valve itself is of the ordinary three-ported kind, and an eccentric fitted to the axis of the driving-wheels imparts motion to the valve-rod. A moment's thought will at once show that the direction in which the engine moves depends upon the position of the eccentric with regard to the crank. Suppose, for instance, that the piston is at the middle of the stroke when the steam is turned on, and that the crank is situated at the same time above the axis; then if the valve be in such a position that the steam is admitted to the top of the cylinder the engine will travel forwards, while if it be admitted to the bottom it will travel backwards. Now the position of the valve will manifestly depend upon that of the eccentric, and this it is almost impossible to make movable. The difficulty is, however, fully met by fitting two eccentrics to the axis, one in such a position as to propel the engine forwards, the other to propel it backwards, and the rods from these two eccentrics are connected to the two ends of a link, as shown on a larger scale in Fig. 46. Here F is the forward and B the backward connecting-rod, and V the valve-rod, the end of which, A, moves in the link. When in the position shown the motion of B is transmitted to V, and the only effect of F is to make that end of the link oscillate. If, however, we depress the link so that A is at the other end, the engine will travel forwards. This link is moved by means of the lever seen behind the handle for turning on the steam, and thus we can depress or elevate the link as we please, and cut off the steam at any required part of the stroke. In our section only one link is shown, but one is of course required for each cylinder, and thus there are in all four eccentrics and two links. Both links are, however, moved by the same lever, and in the quadrant seen behind it there are a series of notches, by which it may be locked in any required position.

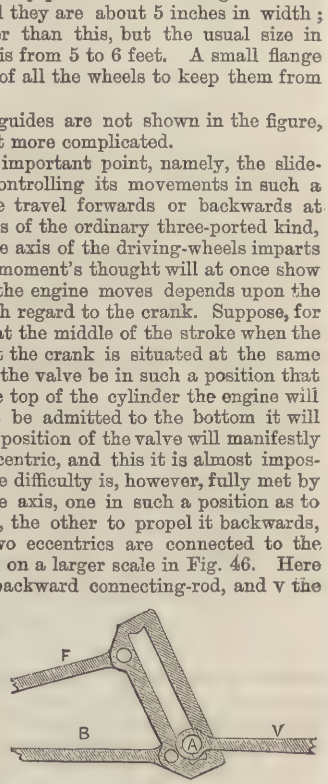


Fig. 46.

The boiler is fed from a tank situated in the tender, and the water is supplied by the pipe seen passing along under the boiler and fire-box. Sometimes the engine is fed by a force-pump, but Giffard's injector is now very generally employed. In nearly all cases the boiler is fed with cold water, all the waste steam being allowed to escape into the chimney. Occasionally, however, a portion is condensed, and the temperature of the feed-water raised in this way. This plan is adopted in many engines on the Metropolitan Railway.

In a few engines which run long distances, an arrangement

is made by which a fresh supply of water can be taken into the tender while the engine is in motion.

A long narrow trough is placed between the rails, and filled with water to a depth of four or five inches; a scoop is then attached to the under side of the tender; this can be lowered at pleasure; and as it passes along, it dips into the water and throws it up into the tank, the speed at which the train travels being quite sufficient to raise the water.

Under the cylinder is seen a piece of iron which comes nearly down to the level of the rails, and serves to remove any obstacle which may accidentally be present on the line. In most American locomotives this is replaced by a large guard of iron rods extending a little way in front of the engine, and known as a "cow-catcher," and in snowy weather this is sometimes fitted with a "snow-plough."

Goods engines are usually made of a heavier and stronger form. The driving-wheels are of less diameter, and two or sometimes three pairs are connected together so as to increase the tractive power. The greater portion of the weight is then made to rest on these, so as to obtain as much hold on the rails as possible. In many foreign engines the number of tubes is very largely increased, and the whole machine is made very cumbrous and unsightly, the boiler being in several instances made to overhang the wheels.

Nearly all lines are now laid of a uniform gauge of 4 feet 8½ inches, that being the width between the rails, and this, of course, limits the dimensions and powers of the engine materially. A wider gauge was laid down on some lines, but from the inconvenience caused by being unable to run over other companies' lines, and also from the greatly increased cost of the rolling stock, this broad gauge is now but little used. A few trains still run on it along the Great Western Railway, but a third line is laid down all along it for narrow-gauge trains, and these are most generally run.

On a few lines a much narrower gauge is used; the best known example of this is a short railway in North Wales, running down from some quarries at Festiniog to the sea-coast. This line is about fourteen miles in length, but its course along the mountain side is very circuitous; it has a gradient of about 1 in 120. The gauge on this is about three feet; and the railway thus constructed has been found to answer well, and is much more economical both in its first cost, and in working.

In some engines the front part, instead of being mounted on a single pair of wheels, is supported on a "bogie" or truck with two pairs. This is connected with the engine by a stout pin, which allows of a certain amount of play, and it is found that an engine thus mounted can travel along curves with much greater ease than the ordinary form. In other engines the bearings of some of the wheels are, with a similar object, so formed as to allow a certain amount of lateral play, which is found very beneficial.

Another important point is to have the wheels carefully mounted on springs, so as to prevent vibration as much as possible. This causes the engine to work much more regularly, and allows the wheels to have a better hold on the rails. Coiled or volute springs and india-rubber blocks are often used for this purpose in addition to the plate-springs shown in the figure.

Several of the wheels are usually fitted with brake-blocks, which may be forced upon them by means of a screw: these very speedily reduce the speed, and bring the engine to a stand.

It is found a very economical plan on extensive railways to make the engines resemble one another as much as possible, so that the various parts may in a great measure be interchangeable, as otherwise an engine may often be standing a long time idle, from some trifling injury. It is often found that a large amount of capital is thus locked up in engines undergoing repair.

We have now explained all the main details of the locomotive; in most other points it closely resembles the engines already described. We must now leave the student to follow out alone the whole details of any engine he may meet with. If after having carefully studied these papers, he can examine a large engine at work, or, failing this, can, when waiting at a railway station, stand by a locomotive and trace out the various parts we have explained, he will find that this practical study will fix firmly on his mind what he has learned, and will clear up any points upon which he may feel at a loss. Careful reading followed by personal observation is always the best plan of acquiring a thorough acquaintance with any subject.

TECHNICAL DRAWING.—XLIII.

DRAWING FOR STONEMASONS.

The subjects of the present lesson are the plan (Fig. 395) and the sectional elevation (Fig. 396) of a cornice and blocking course.

The *cornice* is the projecting course at the top of a building, finished by the blocking course. Cornices are but ramified copings, and are or may be subjected to the same general laws. Care must be taken, however, in arranging them, that their centre of gravity be not brought too far forward in the anxiety to project them sufficiently, lest they act injuriously on the wall

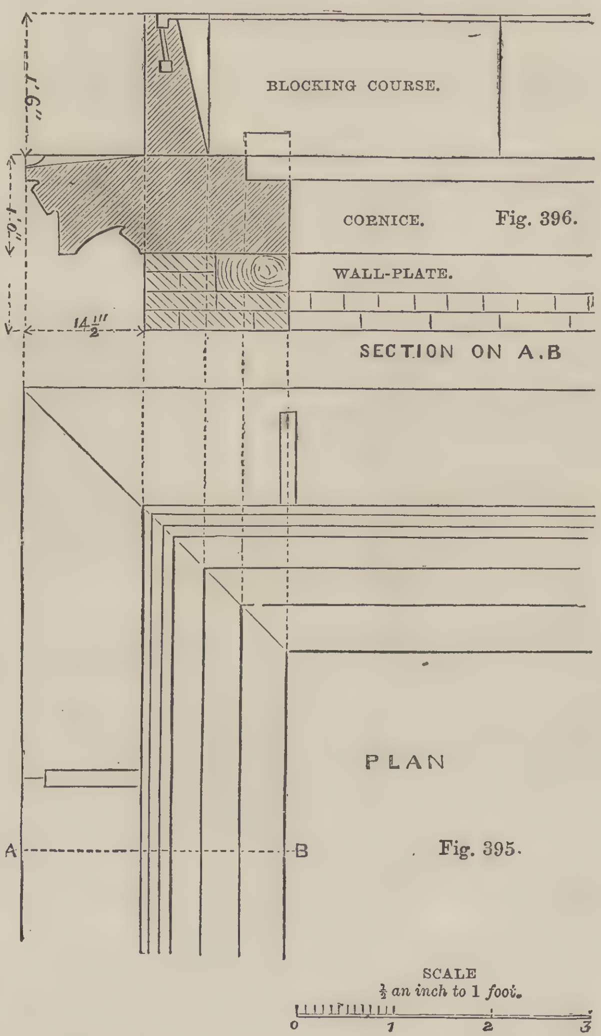


Fig. 396.

Fig. 395.

by pressing unequally, and their own seat be also endangered. A blocking course is either a very thick spring projecting over, or flush with, the face of the lower part of the wall, to cover a set-off, or it is a range of stone over a crowning cornice, to bring the centre of gravity more within the wall than it would otherwise be. In the former case it is treated exactly as a string, excepting that if it be flush below, there will, of course, not be any throating; and in the latter it has a horizontal bed, parallel vertical sides, and a weathered back or upper surface. With these explanations it is hoped the student will comprehend the drawing, and will be able to execute it satisfactorily.

PROJECTION—SECTIONS OF CUBES.

There is no branch of projection which is of more importance to stonemasons than that which treats of sections, and it is, therefore, here proposed to describe and illustrate a few of the

forms which are generated by means of making different cuttings of the cube.

It has already been shown in the lessons in "Projection," that if a cube be so placed as to rest on one side of its solid angles, whilst the base is so raised that one of its diagonals assumes the position of a horizontal line, the diagonal of the solid which connects the front angle of the top with the opposite angle of the bottom, will also be a horizontal line, as shown at A B (Fig. 397); and that if the cube be then rotated on the

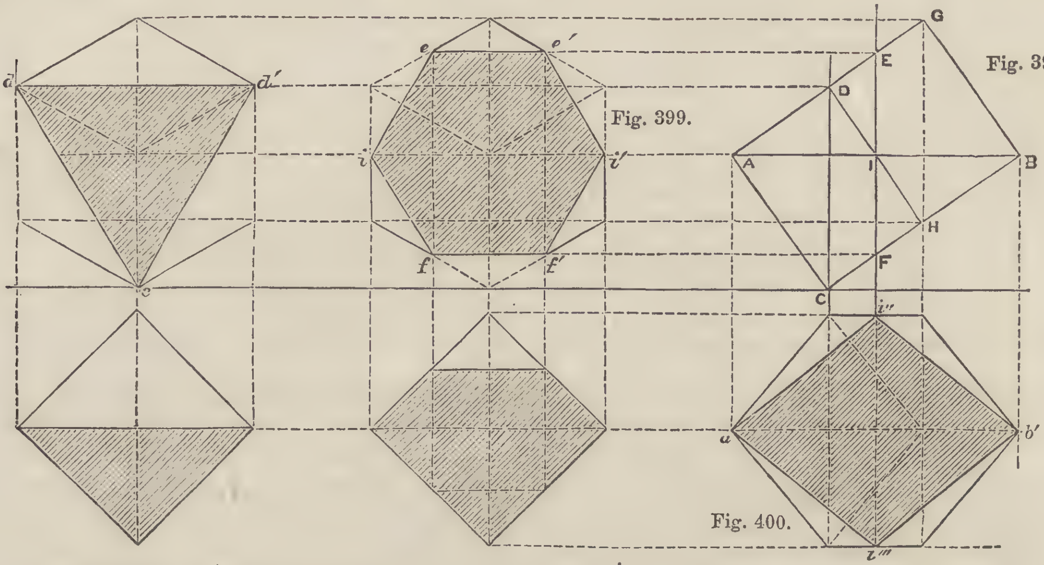


Fig. 398. Fig. 399. Fig. 397. Fig. 400.

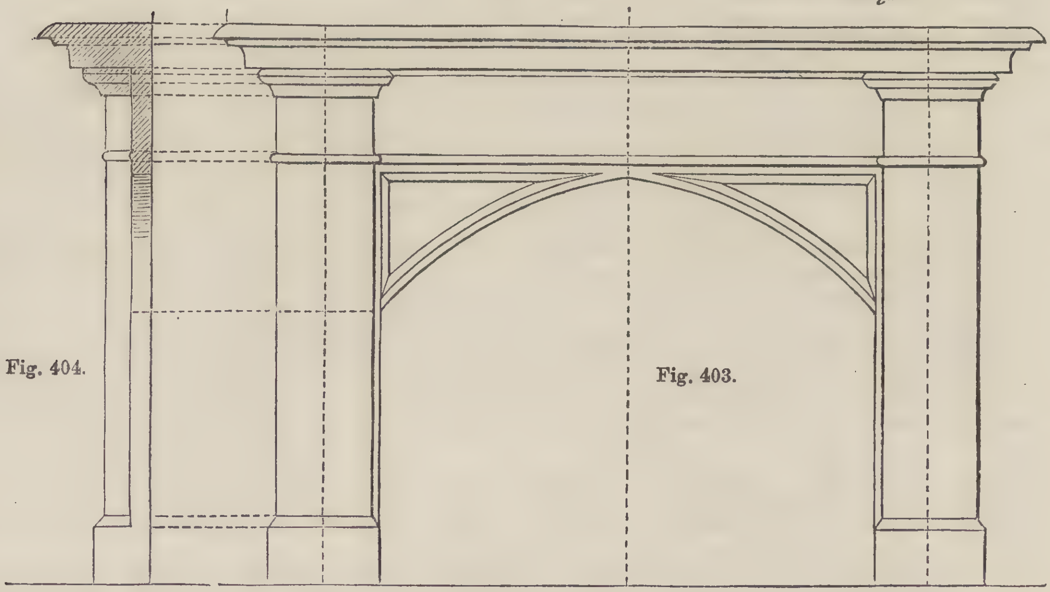


Fig. 404. Fig. 403.

angle C, the front view will be a regular hexagon, shown in Fig. 398. The system of projection on the inclined plane has been fully worked out in previous lessons.

Having proceeded thus far, draw the line D C (Fig. 397), and let us endeavour to find the true form of the section of the cube which would be thus produced.

It will be evident that the point D not only represents the one angle of the cube, but that it hides one beyond it, which becomes visible when the cube is rotated on the angle C, as shown at *d* and *d′* in the front elevation (Fig. 398). Now, if *d* and *d′* be joined to *c*, the true section on D C in Fig. 397 will be found to be an equilateral triangle.

Returning now to Fig. 397, draw the perpendicular line passing through the middle, I, of the line D H, and cutting the edge D G in E and C H in F.

Having now drawn the plan and projection of the cube shown in Fig. 399, draw a horizontal line from I, cutting the projection (Fig. 399) in *i* and *i′*; also draw horizontal lines from E, cutting the projection in *e e′*, and from F, cutting the projection in *f f′*.

Join *e e′*, *e′ i′*, *i′ f′*, *f′ f*, *f i*, and *i e*, and it will be seen that this section is a regular hexagon. Now draw horizontal lines from the angles of the plan of Fig. 399, and perpendiculars from the angles of Fig. 397, thus obtaining Fig. 400, the plan of the cube when raised on the solid angle. Then draw perpendiculars from I, cutting the plan in *i″ i‴*; join *a′ i″ b′* and *i‴*, and the lozenge thus formed will be the horizontal section on the straight line A B.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Fig. 401 in the next page is the elevation of a window, with mouldings and cornice; and Fig. 402 is a section of the cornice and traverse on the line A B.

This example is very simple in its character, but will test the student's power in accurate drawing, since all the lines of the

different members must be truly parallel to each other, and the joints at the angles must be carefully and neatly made.

In commencing this subject, draw the central perpendicular, and set off on it the three parts *a b*, *b c*, and *c d*, representing the three parts—viz., the architrave, frieze, and cornice—into which an entablature is divided.

Next draw the complete rectangle *e f g h*, and set off within it the width *i e* and *h j* corresponding with *b a*.

Lines drawn at 45°, to unite the inner and outer lines of the jamb with those of the lintel, will aid, not only at the present stage, but will be found very serviceable in drawing the mouldings into which the space *a b* is subsequently to be divided.

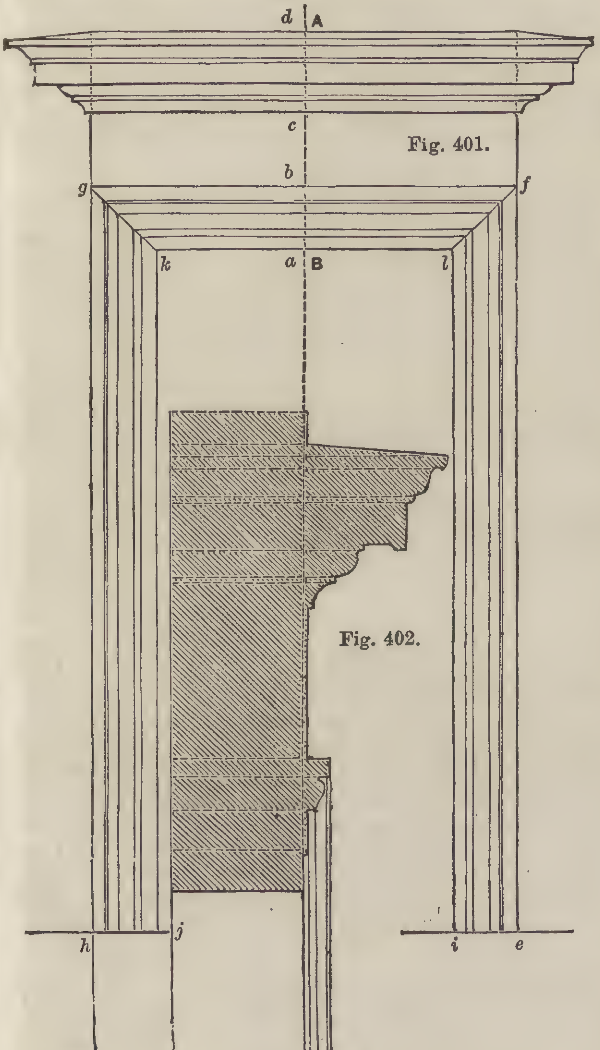


Fig. 401.

Fig. 402.

To draw these separate members, set off the divisions on the central perpendicular between *a* and *b*, and draw horizontal lines through the points of division.

Set off the same points between *e* and *i* and *h* and *j*, and draw perpendiculars through them; these should, if the work be correctly done, meet the horizontals on the lines *f l* and *g k*.

The cornice is now to be completed by drawing the true forms of the ends of the various mouldings of which it is composed. These will be better understood on referring to the enlarged section (Fig. 402), which it is expected the student will, after his previous practice in drawing mouldings, be able to follow without any difficulty.

Fig. 403 is a simple design for a Gothic chimney-piece. A chimney-piece is an ornamental addition to one side of a room, surrounding, and, with the mantel-shelf surmounting, the fire-place. We say *ornamental* addition, because it is not really necessary, since the aperture containing the fire could be simply walled round, without any architectural features to decorate it.

This being so, the chimney-piece should never be too large, but should be in keeping with the size and general features of the room—a consideration often too much neglected.

Chimneys are of comparatively modern introduction, and therefore we have no precedents in ancient architecture in order to direct our taste in the decoration of this construction, whilst on the Continent the heating arrangements differ entirely from ours; and thus it has been mainly in England that chimney-pieces have become special features in interior architecture, the good taste in this department having been introduced by Inigo Jones. Since his time, however, the manufacture of mantel-pieces has become a regular branch of the mason's trade, and, owing to the introduction of machinery in working marble, they are supplied at a much cheaper rate than formerly.

The method of drawing this example is precisely similar to that already shown in the last plate. A central perpendicular should be drawn in each pilaster, and the profile of the mouldings must be set off from it. The arch is of the class termed "segmental"—that is, it is formed of two segments of circles, the centres of which are below the springing.

Fig. 404 is a section through the crown of the arch; the method of projecting this will be easily understood from the example.

CIVIL ENGINEERING.—X.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DOCKS (*continued*).

THE necessity of being able to examine the exterior of a ship from the keel to the bulwarks, for the purpose of cleaning, painting, or repairing, is self-evident, and although it may be possible under emergencies to contrive some method of excluding the water for this purpose from a limited portion of the hull, even whilst the vessel is afloat, yet some means must of necessity be resorted to for placing the entire ship at times in the same dry state she was in previous to launching her.

The graving-dock supplies this means, and whatever method be adopted for obtaining this end may be regarded as a *graving* or *dry* dock. There are two totally distinct methods of removing the water from the exterior of a ship. The oldest, and the most obvious, is to drag the vessel out of the water. This plan, adopted in very early periods by the Greeks, who simply hauled their ships upon the sand, and then raised a bank of earth around them to exclude all access of the water, might have proved sufficiently available for the small ships built in earlier times; but as the size and weight of vessels became greater, the mechanical contrivances known in those days would appear to have failed in accomplishing the result, and the next obvious method was then resorted to—namely, that of excavating the land, and floating the ship into the excavation at high water. This plan in its rudest form is adopted at Hong-Kong; a mere excavation being made in the shore, into which the vessel is floated at high water, a bank of mud protected by fascine work being hastily raised across the entrance at low water; the water which yet remains, or finds an entrance by percolation, being kept under by pumping.

We have here, then, the two methods of dry-docking a vessel: the first, that of raising the vessel out of the water—the plan resorted to in the earliest times, but which failed in the case of large ships until modern engineering skill has enabled us to adopt the same method in the case of the largest vessels; the second method of dry-docking a vessel, and the method the most usually resorted to, that of floating the ship into an artificial excavation at high water, and closing the entrance, when the water can be removed either by the fall of the tide through sluices, or by pumping out. Of course, where the fall of the tide is limited, or, as in the greater part of the Mediterranean, fails altogether, the entire process of removing the water must be by pumping.

The construction of an excavated graving-dock differs essentially from that of an ordinary or floating-dock. They may, in fact, be regarded as the direct converse of each other. In the floating-dock the object is to keep the water *within* the

excavation; in the dry-dock every effort must be made to keep the water *out* of the dock.

The sides of a dry-dock always slope considerably towards the bottom. The depth to which the excavation is carried must depend upon the draught of the vessel intended to enter it, and, like the wet-dock, must be as great over the entrance-sill as the channel of approach. Timber is sometimes employed for lining the sides of small graving-docks, but masonry is preferable, and the floor should in all cases be lined with brick, stone, or concrete. To facilitate access to the dock the sides are constructed with steps, or "altars," which at the same time serve as convenient resting-places to the shores or struts which support the vessel, and retain her in a vertical position after the water is withdrawn. The entrance is closed either by gates or a floating pontoon. If by gates, they are made to open outwards, and conversely to the arrangement of the wet-dock, the union of the shutting-posts is outside the straight line lying between the heel-posts. After a ship has entered the dry-dock she is brought into the centre by hawsers, and as the water is withdrawn and she settles down upon her keel, a proper system of blocks, wedges, and struts must be arranged in order that her vertical weight shall be distributed uniformly over her keel, and her position retained there by horizontal shores. The details of these arrangements need not be considered here, as they belong more properly to naval architecture.

The form of a graving-dock is that of an elongated parallelogram with either rounded corners or curved extremities. In Fig. 18 we show a section of a graving-dock, as seen from either extremity, and in Fig. 19 a plan. The same letters refer to both figures; A, A representing the broad altar usually half-way up; F, F, the floor; C, the entrance, closed either by gates or a caisson.

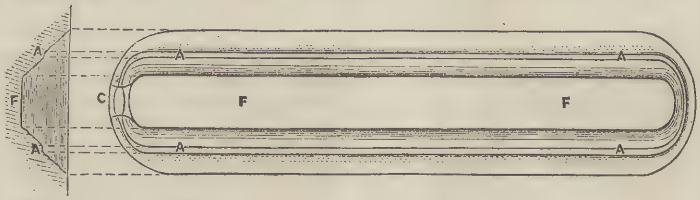


Fig. 18. Fig. 19.

At Boston, U.S., are some fine graving-docks of the kind we have been speaking of. They are 341 feet long, and 80 feet broad at the ground-level. The depth of the dock is 30 feet from the level of the water at high tide; but as the fall of the tide is only 13 feet, 17 feet of water must be removed by pumping. They are lined with granite, and their cost was £150,000 each. The large dry-dock at Portsmouth has the following dimensions:—

	ft.	in.
Length of floor	400	0
,, of coping	426	0
Width at floor	35	0
,, at broad altar	75	0
,, at coping	99	0
Depth from coping to floor	33	10
,, at high-water springs	28	4

The lining is of granite from the floor to the level of the broad altar, 18 feet; the remainder and the floor being finished with Portland stone, bricks, and concrete.

The large dry-dock erected for the United States Government at New York may be instanced as one in which a great amount of engineering skill was exhibited, owing to the very formidable difficulties which had to be overcome; its history is therefore most instructive.

The ground selected for the position of this dock proved to be of an exceedingly treacherous and unsuitable character. The superstratum, for a depth of ten feet, is formed chiefly of decomposed vegetation, the growth of centuries, the annual decadence of the primeval forests which once covered the country. Below the vegetable matter lies an almost impalpable quicksand containing a large proportion of mica. The peculiar characteristic of this sand is its firm, unyielding nature when dry, and its almost fluid state when saturated with water, in which condition it is moved by the slightest current of water passing over it. Trial borings were made to a depth of 80 feet, and unfortunately these borings hit upon a mixture of clay with sand, and although they failed to show the existence of rock, yet the presence of the clay led the engineer to decide upon the position eventually adopted. The discovery of clay was truly a misfortune, inasmuch as it was subsequently discovered that the clay was confined to a very small portion of the area required for the dock, the remainder being nothing but quicksand of the nature described. The presence of sand led to the necessity of constructing an immense coffer-dam which should entirely surround the future dock, in order to resist the pressure of the treacherous soil, and keep back the water which percolated through it, since the foundation of the superstructure had to be laid 37 feet below mean-tide. The original dam was commenced in 1842, and the piles used in the first instance were of yellow pine, 15 inches square, and from 35 to 40 feet long, secured at the top and at the level of low water by horizontal wailings of oak 12 inches square, firmly bolted and tied once in every 10 feet with iron tie-bolts 2 inches in diameter. A change occurred at this period in the superintending engineer, and the new superintendent deemed it desirable to give up the use of yellow pine, in consequence of the hardness of the bottom soil splitting and shattering the wood under the blows of the pile-driver. Green timber was accordingly employed with success.

The dam was completed according to the original plan in 1846, being 470 feet long, and from 60 to 100 feet wide, with wings 175 feet long and from 15 to 30 feet wide. The framework stood well the removal of about 30,000 cubic yards of soil, but when only 6 feet of water had been pumped out, it became evident that the dam would yield to the external pressure. The result was that nearly the entire length of the north-west wing was forced in at the top, and very shortly afterwards a part of the front of the dam was forced outwards, breaking some of the iron tie-bolts; and as the water continued to be withdrawn, nearly every part of the dam yielded more or less. This obvious weakness in the original construction resulted in the necessity of driving an additional row of piles inside the former row, and entirely round the dam, the piles penetrating to a greater depth than the former ones. With this additional strength, however, the dam yielded at one point, piles settling down vertically 3 feet which when drawn were found to measure from 33 to 37 feet in length. Water had evidently penetrated beneath them; consequently fresh piles 50 feet long were driven along the face of the dam, whilst another row of equal length was driven parallel to these and at a distance of 30 feet from them, for a length of 200 feet opposite the portion which had yielded. A month or two after this a third breach occurred at the north-west angle of the dam, and was first indicated by a sudden increase in the flow of water in one of the bottom springs, and also by its change of character from fresh to salt; the change alternating several times within a few minutes; and in less than an hour the volume of this spring had increased to five times its former amount, bringing up in its waters immense quantities of the black mud which overlays the quicksands in the bottom of the bay. Some of the piles shortly settled down vertically from 5 to 6 feet, and in this instance again the evident cause of the breach was the insufficient length of the piles. Subsequently fresh piles of from 50 to 62 feet long were employed; yet so unstable was the material upon which the dam rested, that although the piles penetrated it from 15 to 25 feet below the foundations of the dock, it still continued at times to yield to the pressure of water and soil, and was only sustained by the closest watchfulness.

As the excavation proceeded, and as consequently the support afforded internally by the soil was withdrawn, it was found necessary to attach chain-cables of iron two inches in diameter to the dam, and secure them to mooring blocks on the shore; these cables were, however, frequently broken, no less than six being fractured in one night upon one occasion. Gradually, as the work progressed, rows of foundation-piling were driven in front of the main piles, and at a few feet distant, buttresses of earth being left behind them, and against these struts of timber were planted, their heads pressing against the dam. The masonry on the foundation was laid in sections, and braces were likewise extended from it to the dam. The thrust upon these braces was so enormous, that on one occasion it had the effect

of moving bodily a mass of masonry exceeding 250 tons in weight.

The coffer-dam was composed of a number of piles reaching a total of 3,504, their average length being 39 feet, and having an average section of 15 × 15 inches; the entire cost of the dam, including repairs to breaches, being £51,243 11s. 9d.

The *excavation* for the dock covered an area of 2 acres at top, and rather more than 1 acre at bottom, and extended to a depth of 42 feet; being 37 feet below mean high-water, and required the removal of 112,000 cubic yards of earth; the semi-fluid nature of the soil rendering its removal both difficult and expensive. The cost of excavation alone was £29,463 12s. 11d.

The obstacles opposed to the progress of the work from the number and magnitude of the fresh-water springs found at the bottom of the excavation were immense. They were wholly unconnected with the tides, as was evidenced by their difference of temperature and perfect freshness, and proved that their origin came from a far higher level, by their pressure. The water they discharged contained a large proportion of exceedingly fine sand, there being from 17 to 27 ounces of sand in from 33 to 38 gallons of water. The largest of the springs discharged 10 gallons of water per minute. The sand was of the same character as that in which the piles were driven, and the danger of its removal arose from the gradual undermining of the whole coffer-dam. It was utterly impossible to check the flow of the water with safety, as its pressure under accumulation was found sufficient to raise the foundation, however heavily loaded. It was therefore necessary to provide for its flow, and at the same time to check the escape of the sand. So great was the pressure of the pent-up water that in one case it burst up through a bed of concrete 2 feet thick; and this outburst being checked, it in a few days burst up through another bed 14 feet distant. The ultimate course adopted was as follows:—An area of 1,000 square feet around the troublesome spring was laid with plank; upon this was laid a floor of brick in dry cement, and upon that another layer of brick with Roman cement. The space was next filled with concrete, and the foundations completed over all with the utmost despatch, vent-holes being left through the floor and foundations. By this means the exit of the spring was forced up to a level 10 feet higher, and it was then found to run free from sand.

During some severe weather in 1848, two of the springs were closed by freezing, and as a consequence forced up 1,200 feet of the foundation, including the first course of stone, which was from 12 to 15 inches thick. None of the springs were closed until the inverts had been laid and the cement well set, and when closed they exerted an upward pressure so great as to force the water through the joints of the masonry, without, however, disturbing the stone-work. A 25 horse-power engine was kept in constant work to keep under the in-flow of water, the cost alone of temporary drainage being £14,142 10s. 10d.

The entire superstructure of masonry rests upon bearing piles from 25 to 40 feet long, and averaging 14 inches in diameter at the head. They consist principally of round spruce. The sheet-piles are of yellow-pine plank 5 inches thick, and averaging 15¼ feet long. The character of the soil was such that it was deemed expedient to drive as many piles as could be forced into the earth, and they were for the most part driven up to the point of absolute resistance, and whenever a weight of 2,000 pounds falling 35 feet ceased to drive a pile more than 3 inches at a single blow, another and a larger pile was driven alongside it. Each pile while being driven was protected at the head by a band of iron 1 inch thick and 3 inches deep, made of the toughest iron that could be produced. The total number of round piles under the foundation is 6,539, and of sheet piles 1,744. The greater number of these piles were driven by hammers or "monkeys" weighing from 2,000 to 4,500 pounds each, falling from 30 to 40 feet, and the average number of blows given with the smaller hammer was 151, and with the larger hammer 50; an instructive fact, showing the advantage resulting from the employment of a heavy hammer for pile-driving, since a hammer weighing only 2·25 times another hammer, performed fully three times the work. A small portion of the piles—541—were driven with a Nasmyth's steam pile-driver, but its frequent derangement prevented its relative value being fairly tested.

The foundation of the dock was laid on the levelled heads of the bearing-piles in the following manner:—Concrete masonry 2 feet deep was laid between the bearers and levelled with their heads, which were then capped with yellow pine of a scantling 12 × 14 inches laid transversely with the axis of the dock, and fastened to each pile with trenails. Concrete was again laid between these timbers and raised to a level with them, and a flooring of 2-inch yellow-pine plank laid upon and spiked to them. Another and a similar course of timber was laid upon this floor, breaking joint with the lower planks and trenailed to them; the intervals were again filled with concrete, and another floor of plank laid over all. The concrete employed was composed of 1 part of hydraulic cement carefully tested; 2 parts of coarse, clean sand; 3½ parts of broken stone; and 2½ parts of beach pebbles; the cement and sand being first mixed into a mortar, then the broken stone added and well mixed, and lastly the pebbles. The cost of the foundation to the point indicated was £32,115 9s. 10d.

The apron of the dock extends for a distance of 45 feet into the channel of the bay, the foundation of the apron being strengthened by additional piles whose heads were covered with bevel-hewn timber secured by trenails, the space around and between the piles being filled with concrete to a depth of 2 feet; whilst dovetailed stone blocks are placed between the timber to prevent their floating, the whole being covered with 3-inch plank.

In the foundation and superstructure of this dock 80,000 tons of stone were employed. The masonry foundations are 400 feet long and 120 feet broad. The dock is capable of being used either in whole or in part, there being gates placed intermediately between the extremity and the entrance at a distance of 52 feet from the latter; the entrance itself is closed by a caisson. The main chamber is 286 feet long and 30 feet broad at the bottom, and 307 feet long and 98 feet broad at the level of the coping; and the entire length available at mean high-water is 350 feet. The least width is at the hollow quoins of the gates, where the dock narrows to 68 feet, and the least depth is over the mitre-sill, where the water is 26 feet deep at high-water. The vertical height of the wall is 36 feet. The flooring of the dock is an inverted arch formed of stone from 4 to 6 feet deep, each stone being very large and heavy, the smallest weighing over 3,000 pounds, and many over 15,000 pounds. The mitre-sills are of granite blocks of immense size, the key-stone before being cut having had an estimated weight of 50 tons; after being dressed it weighed 43,300 pounds.

The cost of the masonry, exclusive of cutting the stone, was £89,515 15s. 8d., and the cost of cutting was £50,009 19s. 8d.

The gates are of iron, and with the machinery for working them weigh 187 tons 8 cwt. Their entire cost, including machinery, was £13,989 3s. 4d. They are curved on the interior face to a radius of 74 feet 9 inches, which of course corresponds with the curve of the mitre-sill, and 76 feet 8 inches on the exterior face. They can be closed in ten minutes by four men to each leaf.

The caisson is an iron vessel 50 feet long at the keel, and 68 feet 8 inches at the top. The breadth of beam is 16 feet at the mid-ship section, and 7 feet at the keel. The keel and stems are built up of plates of ¾-inch iron to a combined width of 2 feet, and have a projection of 9 inches. The frame is composed of vertical ribs of iron, 31 on each side, bent to the form of the vessel, and covered with boiler plate stiffened at the contact with the ribs with angle iron. The thickness of the plates varies, being of ¾-inch iron at the bottom, and diminishing gradually by ⅛ to ¼-inch at the top; the whole being secured to the ribs by rivets. The interior horizontal layers or decks are supported by hollow cast-iron columns, 6 inches in diameter and 4 inches bore, through which are passed 3-inch wrought-iron rods, secured to the keel-plate and main-deck by keys. The weight of the caisson is 217 tons 9 cwt. 73 pounds, and carries a weight of 105 tons 11 cwt. 63 pounds as ballast. Its cost was £18,544 15s. 4d. The pumps for removing the water from the dock are capable of emptying it in 2⅛ hours, its capacity being 610,000 cubic feet. The steam-cylinder actuating the pumps is 50 inches diameter, and 12 feet stroke. There are two pumps, each barrel being 63 inches diameter, and 8 feet stroke.

The removal of the coffer-dam after the construction of the dock was completed was a work of considerable difficulty. The first pile drawn from the outer row required a force of 630 tons to start it out of the earth. No application of chain-cables and levers were of any use, but they were finally extracted by a "Dick's Anti-friction Press" worked by four men.

The dock occupied from first to last a period of ten years in construction, and has involved a total cost of £449,357.

PRINCIPLES OF DESIGN.—XX.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS, AND WOVEN FABRICS GENERALLY.

BEFORE we leave the consideration of carpets we will state in axiomatic form the conditions which govern the application of ornament to them, as reference can more easily be made to short concise sentences than to more extended remarks.

1st. Carpet patterns may with advantage have a geometrical formation, for this gives to the mind an idea of order or arrangement.

2nd. When the pattern has not a geometrical basis, a general evenness of surface should be preserved.

3rd. Carpets are better not formed into "panels," as though they were works of wood or stone, but should have a general "all over" effect, without any great accentuation of particular parts. The Indian and Persian carpets meet this requirement.

4th. While a carpet should present a general appearance of evenness, parts may yet be slightly "pronounced" or emphasised, so as to give to the mind the idea of centres from which the pattern radiates.

5th. A carpet should, in some respects, resemble a bank richly covered with flowers; thus, when seen from a distance the effect should be that of a general "bloom" of colour. When viewed from a nearer point it should present certain features of somewhat special interest; and when looked at closely new beauties should make their appearance.

6th. As a floor is a flat surface, no ornamental covering placed on it should make it appear otherwise.

7th. A carpet, having to serve as a background to furniture, should be of a somewhat neutral character.

8th. Every carpet, however small, should have a border, which is as necessary to it as a frame is to a picture.

Fig. 69.

Having thus summarised the principles that govern the application of ornament to carpets, we may proceed to notice the conditions governing the decoration of other woven fabrics.

The first thing to be considered is the nature of the cloth on which the pattern is to be worked—whether it is of open or close texture. Fabrics of an open character should bear upon them a larger pattern than those which are thicker or closer. The openness or closeness of the fabric will thus determine, to an extent, the nature of the ornament which is to be placed upon it. Muslins, being open in character, should have larger patterns than calicoes, which are closer in texture, or the pattern will be indistinct in the one case or coarse in the other.

But not only does texture influence the pattern when considered as to coarseness or fineness, but also the nature of the cloth as regards material. Thus silk will bear greater fulness of colour than muslins or calico-prints, owing to the fact that the lustre of the material, by reflecting light to the eye of the observer, destroys a certain portion of the intensity of the effect of colour which a less reflective material would exhibit. Silk, as a material, also conveys to the mind an idea of costliness or worth, and wherever the material does so the pattern may be richer in colour than it should be in cheaper and commoner fabrics. If a pattern is in two tints of the same colour only, as in the case of those woven silks where the pattern is formed by the contrast of "tabby" and satin, it may be considerably larger than in those cases where it is rendered conspicuous by colours.

This latter remark will apply also to damask table linen, and to all similar materials, as well as to dress fabrics, and draperies such as window hangings; but of these we shall say a word shortly.

The closeness or openness of a fabric should, then, be considered when we design patterns for their enrichment, and so should the nature of the material, as this will influence its deadness or lustre. But there are also other considerations which must not be lost sight of. If the pattern is to be wrought by printing, then one class of conditions must be complied with; if by weaving, then another class of requirements call for consideration.

The requirements of manufacture are much more numerous than might be supposed, and are in some cases very restrictive. The size of the repeat, the manner in which colour can be applied, the character of surface attainable, and many other considerations have to be carefully complied with before a pattern can appear as a manufactured article.

The chief fault of patterns, as applied to fabrics generally, is their want of simplicity, want of simple structure, want of simple treatment, want of simplicity of effect; and together with this we generally find largeness and coarseness of parts.

These errors arise largely out of a want of consideration of the capabilities of the material. What can be done with this or that particular fabric, is a question that we should carefully ask ourselves before we think of preparing a design. Have we colour at our disposal, or texture merely? and if colour, can it be employed freely or only sparingly? and can any colours be placed in juxtaposition or only certain tints? These are questions of great importance, and they should be asked and carefully considered before the first step is taken towards the formation of a pattern. Having ascertained what can be done with the material at command, let us ever remember that we should always endeavour to so employ the capabilities of a material as to conceal its weakness and emphasise its more desirable effects. If this consideration were always given by designers to the power which the material has of yielding effects, we should see, in very many instances, effects strangely different from those which we often encounter; and this remark applies to no class

of fabrics more fully than to damask table-linen and coloured damask window-hangings.

No satisfactory effect can be got in light and shade upon any woven or printed fabric; besides, to attempt such a mode of treatment is absurd. Light and shade belong only to pictorial art. The ornamentist when enriching a fabric deals only with a surface, and has no thought of placing pictures thereon; he has simply to enrich or beautify a surface which without his art would be plain and unornamental. A picture will never bear repetition. Who ever heard of a man having two copies of one picture in a room? Yet how much more absurd is it to repeat a little picture—perhaps a pictorially rendered flower—a hundred times over one surface! Besides this, a surface must always be treated, for decorative purposes, as a surface, and not in a manner calculated to deceive by giving apparent relief, or thickness, to that which is essentially without thickness. Take a common damask table-cover. This is by custom always white, although it would be better if of a deep cream colour, or buff; and the pattern which it bears results from a change of surface only (why a margin of "ingrain" colour is not added, I could never see); yet in nine cases out of ten the pattern which is presented by such a fabric is a miserable shaded attempt at a pictorial treatment, and is also a thorough failure.

Simplicity of pattern naturally accords with a simple mode of production, and the means of producing pattern in damasks is certainly most simple. Yet that there is a natural harmony between simplicity of pattern and simple means of producing an art effect is obvious, for of all patterns that I have ever seen upon damask table-linen the simple spot, or dot, is the most satisfactory. If, combined with this spot, we have a border formed of a simple Greek "key-pattern," or of mere lines (a very usual border to good cloths), the effect is perfectly satisfying, and, as far as it goes, is highly to be commended.

It is curious that this spot is only sold in the better quality of table-linen (at least so they tell me in the City), and this shows that the wealthy, or, in other words, the educated, buy such patterns, as they prefer the true to the meretricious, while the false and showy devices which we see on the common cloths please only the common people of vulgar taste. I am not sure, however, that many persons, whose means are limited, would not buy spots and other simple, but correctly treated, patterns, if such were to be got in common qualities of damask; but when the pocket must govern the purchase, it is hard to say that the false is preferred to the true, if the true is not procurable with the means at command.

While I cannot withhold praise from this little spot, it must not be thought that I thereby give to it a high place as an art work. Little is here attempted, and that little is done well. But let us analyse this pattern. First, the spots are of one tint throughout, if I may thus express myself—a tint, shall we say, which is the reverse of that of the ground. It is not shaded so that it may appear as a ball or globe, and is not graduated in "colour" in any way (were it graduated or shaded, feebleness of effect must inevitably accrue), but is a simple, honest spot, treated as a surface ornament. Second. This spot is geometrically arranged, or, in other words, has an orderly arrangement.

If an attempt is made at rendering a pictorial, or light-and-shade effect in damask, an absurd failure can alone result, for depth of shade is nôt obtainable in the material; and, besides this, what appears as shade, when the cloth is seen from one point of view, appears as light if seen from another point of view. Nothing could be more absurd, then, than seeking to produce shaded effects with such means as are here at our disposal. But were the fabric capable of rendering such effects, it would still be wrong to employ them, as we deal only with the surface, and are seeking to enhance the value of, or beautify, a fabric, and not to cover it with pictures. In our simple spot-pattern we have those elements which may be extended into the richest and most artistic damask patterns. We have order—as indicated by the geometrical plan of the pattern—and an honest and simple expression, or application, of the capabilities of the material.

Fig. 70.

All table-covers should certainly have a border. Any object which is to be used as a whole looks unsatisfactory if it appears as though it were a part of a whole. If a cloth is without border it is impossible to avoid the impression that it is a part of a larger cloth, and in every respect the general effect is decidedly unsatisfactory.

I introduce into this article two illustrations of woven fabrics. The first is that of Austrian cloth of gold (Fig. 69), the second of Indian embroidery on cotton (Fig. 70); but of these I shall speak in my next paper on this subject. I insert them in this article with the view of leaving room in my next chapter for some additional illustrations of woven fabrics which will aid us in our studies.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XVIII.—JAMES FERGUSON, F.R.S.

BY JAMES GRANT.

JAMES FERGUSON, an eminent and self-taught mechanist and philosopher, inventor of the astronomical rotula, of a universal dialling cylinder, etc., was born in 1710, in the little village of Keith, in Banffshire, in the north of Scotland. His parents were very poor, but very religious and honest; as he states himself, "they lived in good repute with all who knew them, and died with good characters." His father was a mere cottar, and supported a large family by his daily labour, and the profits that arose from a few acres of land which he rented. Thus he could afford to bestow but little upon the education of his children, yet they were not neglected, for in his leisure hours he taught them all to write and read, and it was while he was teaching his eldest boy the Scottish catechism that James, the younger, learned to read; after he could do so perfectly, his father sent him to the grammar-school at Keith for three months, and that was all the education he ever received at a seminary.

His taste for mechanics arose from a very simple accident. When eight years of age, a part of the thatched cottage in which the family dwelt being decayed, his father frugally set about repairing it with his own hands. To his great astonishment, the child saw him lift up the whole roof as if it had been a small weight; and this he attributed to a degree of strength which excited his terror as well as wonder; but a little observation soon enabled him to perceive that his father applied his hands, not to the roof itself, but to the end of a lever. Little James therefore proceeded to amuse himself by making levers —bars he called them—and, by applying them in different ways, he discovered that the power gained by the bar was just in proportion to the lengths of the different parts of the bar on each side of the prop.

Thinking it a pity that by means of this bar a weight could be raised but a very little way, he imagined that by pulling round a wheel the weight might be raised to any height, by tying to it a rope, and winding the latter round the axle, and that the power gained thus must be exactly as great as the wheel was broader than the axle was thick. He found it to be just so, by hanging one weight to a rope put round the wheel, and another to the rope that was coiled round the axle; so that in these two machines it appeared very plain that their advantage was as great as the space gone through by the working power exceeded the space gone through by the weight. By means of a turning-lathe which his father possessed, and penknife, he contrived to make wheels and other things necessary for his machines, or models, illustrative of this power.

Imagining that it was the first idea of the kind that had ever been formed, the boy wrote a short account of his invention, and made diagrams of it with pen and ink; but on showing them to some one, he was informed, to his mortification, that such appliances were well known already, and his friend gave him a work on engineering, in which they were fully treated of and described. As his father could no longer afford to maintain him in what seemed idle pursuits, and the boy was too weak and young for hard work, he became what is termed "a herd laddie," and was hired by a neighbouring farmer to keep his sheep. In this humble occupation his earlier years were passed, and amid the pastoral solitude of the Banffshire glens, and by the shore of the Moray Firth, he learned to study the stars when lying amid his sheep by night; and all day long he amused himself by making models of mills, and spinning-wheels, and other mechanical contrivances, even to constructing for his own use a celestial globe.

His employer having observed that often in the evenings, when farm work was over, he went out into the fields, and, with a blanket or plaid about him, lay down on his back, and stretched a string with small beads upon it at full arm's length between his eyes and the stars, sliding the beads to and fro till they hid certain stars, laughed at him as being guilty of folly. But when the shepherd explained that he did so in order to take their apparent distances from each other, and that then, by laying the thread upon paper, he marked the position of the stars thereon by the beads, the farmer, who was a kind and indulgent man, encouraged him to go on, and actually did Ferguson's outdoor work at times, that he might in the day-time make fair copies of what he had done in the night. The Rev. John Gilchrist, minister of Keith, who had known him from childhood, on seeing what Ferguson called his "star-papers," kindly supplied him with some maps, ink and paper, a pair of compasses, and a ruler; but as copying the maps required more time than he could reasonably expect from his master, the latter, says Ferguson, in the preface to his "Select Mechanical Exercises," "often took the threshing-flail out of my hands and worked himself, while I sat by him in the barn, busy with my compasses, ruler, and pen." Having completed the copy of a particular map, he called at the manse, and while he was showing it to the minister, Thomas Grant, the Laird of Achoynaney, chanced to come in. The clergyman introduced the lad to him; and he was so pleased with his apparent genius that he offered Ferguson a room in his house, adding that if he came to live there the butler, another self-taught man, could give him a deal of instruction. This was too good an offer not to be accepted. He went to reside in the house at Achoynaney, and by the butler, whose name was Alexander Cantley, he was taught decimal arithmetic, algebra, and the elements of geometry. Nor were these the only parts of the butler's education, for it seems that he was a perfect mathematician, master of every musical instrument except the harp; that he knew Latin, Greek, French, and even some of the elements of surgery. On the butler obtaining a situation in the Earl of Fife's family, Ferguson declined to remain longer in Mr. Grant's house; he returned home, and proceeded to make for himself a globe, with a meridian ring and horizon; but all this skill and knowledge would not as yet give him bread, so he took service with a miller, with whom he remained a year, and was so starved for want of victuals, his master being a drunkard, that he was too often glad to get a little oatmeal mixed with cold water for food; so he returned once more, in a very weak state, to his father's thatched cottage.

There he constructed for his own use a watch, with wooden wheels and a whalebone spring, and this he enclosed in a wooden case, the size of a breakfast cup; but a clumsy neighbour to whom he was showing it let it fall on the clay floor, and it was broken to pieces. This discouraged him so much that he never attempted to make another; but his extraordinary ingenuity having now procured him the notice of Sir James Dunbar, of Durn, and several other county gentlemen, they endeavoured to assist him by their countenance and advice. He was employed to clean their clocks; and having learned drawing, he now began to take miniatures in Indian ink and make patterns for ladies' needlework, and the payments he received for these services enabled him to supply the wants of his father, who was now too frail to labour, and descending into the vale of years.

The gate pillars of Durn House were surmounted by two large globular stones; and on these he painted in oil-colours a terrestrial and celestial globe. "The poles of these painted globes stood towards the poles of the heavens; on each the twenty-four hours were placed around the equinoctial, so as to show the time of the day when the sun shone out by the boundary where the half of the globe at the time enlightened by the sun was parted from the other half in shade; the enlightened parts of the terrestrial globe answering to the like enlightened parts of the earth at all times. So that, whenever the sun shone on the globe, one might see to what places the sun was then rising, to what places it was setting, and all the places where it was then day or night, throughout the earth."

Half his nights were spent in gazing at the stars, and taking the places of the planets by his string and beads. By observing what constellations the ecliptic passed through in his map, and comparing these with the starry heavens, he became, in his enthusiasm, so impressed at times that he imagined he saw the ecliptic in the blue dome above, "like a broad circular road for the sun's apparent course; and fancied the paths of the planets to resemble the narrow ruts made by cart-wheels, sometimes on one side of a plain road and sometimes on the other, crossing the road at small angles, but never going far from either side of it."

Having married in May, 1739, and having, during a two years' residence in Edinburgh, studied anatomy, surgery, and physic with great intensity, he returned to his native village of Keith, with a stock of medicines and plaisters, etc., and endeavoured to establish himself as a doctor; but, to his mortification,

he found that all his medical theories were of little use in practice. Thus he soon relinquished the attempt; and after endeavouring to make a livelihood by "picture-drawing" at Inverness for eight months, he began to think of astronomy again, and contrived and finished a scheme on paper for showing the motions and places of the sun and moon in the ecliptic on each day of the year perpetually, and, consequently, the days of all the new and full moons.

To this he wished to add a method for showing the eclipses of the sun and moon. By 1740 his astronomical rotula was complete; and having got the plates engraved, he published it, and this ingenious and brilliant invention sold very well until 1752, when a change in the style rendered it comparatively useless.

In Edinburgh he was befriended by Colin Maclaurin, professor of mathematics in the University. One day he requested the latter to show him his orrery, and was greatly delighted with the motions of the earth and moon in it. After long thought and calculation, Ferguson found that he could contrive the wheel-work requisite for turning the planets in such a machine, and giving them their progressive motions; but felt that he should be very well satisfied if he could construct for himself an orrery to show the motions of the earth and moon, and those of the sun round its axis. This machine he partly constructed with his own hands, and partly with the aid of a turner: and when in action it showed completely the sun's motion round its axis; the diurnal and annual motions of the earth on its inclined axis, which kept its parallelism in its whole course round the sun; the motions and phases of the moon, with the retrograde motion of the nodes of her orbit; and, consequently, all the variety of seasons, the different lengths of days and nights, the new and full moons, and eclipses.

After making a smaller and neater one, with all the wheels of ivory, in May, 1743, he took it to London, where it was bought by Sir Dudley Ryder. Still, he could neither live nor support his wife and three children by the construction of orreries, though he made six, each of which was always more perfect than its predecessor; and had to resort once more to taking miniatures, his chief patron being a Mr. Stephen Poyntz, who resided near St. James's Palace. But astronomy was ever uppermost in his thoughts; and after constructing a very simple machine for describing the paths of the earth and moon in the firmament, he showed it to Mr. Martin Folkes, then President of the Royal Society, who expressed his admiration for the contrivance, and that same evening presented it and Ferguson at a meeting of the society, and thus won him many new friends.

In 1747 he published a dissertation on the phenomena of the harvest-moon, with the description of a new orrery, in which there were only four wheels; but never having had a finished education, nor time to study the rules of composition, he put it to press with extreme doubt and diffidence. On finding, however, that the work was well received, he was encouraged to proceed, and successively issued his "Astronomy," "Mechanical Lectures," "Tables and Tracts relative to Several Arts and Sciences," the "Young Gentleman and Lady's Astronomy," and a treatise on "Electricity."

The year 1748 found him publicly lecturing on these subjects in London, with great success, and also on hydrostatics, hydraulics, pneumatics, and his universal dialling cylinder.

When he had been thirty years in London, he was introduced to the notice of George III., who, when Prince of Wales, had attended his earlier lectures, and who bestowed upon him a pension of £50 per annum; thus by his talents and industry rising from the humblest ranks of the peasantry to become the preceptor of a king.

In 1754 he brought out a brief description of the solar system; but his greatest work is his "Astronomy, explained upon Sir Isaac Newton's Principles, and made easy to those who have not studied Mathematics." His delineation of the complex line of the moon's motion procured him in 1673 the honour of being elected a member of the Royal Society of London, without the payment of the usual fees.

The first edition of his "Dissertation on the Harvest Moon" appeared as early as 1747. His "Easy Introduction to Astronomy" passed rapidly through eight editions in Germany, after its first appearance there in 1771; and Madame Genlis, in her preface to the "Tales of the Castle," remarks that it is a work so perspicuous, that a child only ten years of age may understand it completely. In 1770 he was chosen a member of the American Philosophical Society; and five years afterwards he published "Two Letters to the Reverend John Kennedy, containing an account of many mistakes in the astronomical part of his Scriptural Chronology, and his abusive treatment of astronomical authors."

These were followed by a third letter on the same subject. Some of his writings were translated into French by P. R. Levecque, and they attracted considerable attention among the learned bodies of Paris. The obscurity of his early life, together with the humble situation and indigent circumstances of his father having required that he should—as we have related—engage in the capacity of a shepherd and farm-servant, was the cause of a curious misconception in France, where the astronomer Lalande in his writings speaks of him, in the first volume of his "Astronomie" (page 163), as the "berger du Roi d'Angleterre en Écosse" (the Shepherd to the King of England for Scotland).

By his lectures, his various works, and his frugality, Ferguson amassed a considerable sum; and, ultimately, was enabled to live with ease and comfort in London. The best and most useful work he ever wrote—viz., his "Lectures on Select Subjects in Mechanics, Hydrostatics, etc."—passed through many editions, and has contributed much to the diffusion of mechanical knowledge among all classes of people. A new edition of it, in two vols. 8vo, with an appendix, containing an account of all the more recent inventions and discoveries, was published by Sir David Brewster in 1805, and another edition was required in the following year.

His "Select Mechanical Exercises" appeared in 1773; "The Art of Drawing in Perspective" in 1775; and he communicated many papers to the Royal Society, which were published in their "Transactions." Though thus successful in his scientific career, he was not without afflictions in his latter years. His daughter, a girl of great beauty, was unhappily lost to him in her eighteenth year; his eldest son, Murdoch Ferguson, became a surgeon, went to sea, and, by a shipwreck, lost all he possessed. His second son studied physic at the Marischal College of Aberdeen, but nothing more is known of him.

After a long and useful life, this singular man, whose career began as a poor shepherd boy among the Banffshire hills, and "who might be called an enthusiast in his love of God, if religion founded on such substantial and enlightened grounds as his was could be like enthusiasm," died at London, on the 16th of November, 1776, quite worn out by study, age and infirmity.

OBJECT DRAWING.—VIII.

The outline of the group (Fig. 44, page 288) having been thus completed, we proceed with the shading, and it will be seen that in the example the light is placed on the left side and higher than the pyramid; it will therefore be evident that the brightest light will be on the left side of the most prominent angle of the pyramid, and then on the left side of the prominent edge of the oblong block and of the cube. The right-hand side of the whole group will, of course, be shaded. The margin of the base of the pyramid, too, will be in shade, but its tone will be rather darker than that of the sides; whilst the shadow cast on the oblong block by the projecting pyramid, and the cast shadows on the ground and on the upper surface of the cube, will be the darkest of all.

It must be remembered that the most brilliant lights and deepest shadows are those nearest the eye, and that both of these diminish in intensity as their distance from us is increased. In shading, therefore, we must follow this natural effect. Thus, in the present group, the brightest light follows the most prominent angle. The surfaces, however, do not remain equally bright over their whole breadth, but the light gradually tones down as the surface recedes. Similarly, the shade on the right side is darkest where the surface is the most prominent, and the depth of colour is softened down as the distance increases.

This is sometimes called *aërial perspective*, or the perspective appearance caused by the air, for the farther an object or surface is removed from the eye, the greater will be the mass of atmosphere intervening, and thus a sort of medium is formed through which the object is seen more or less distinctly, according to the denseness of the air. Thus, in a clear day,

distant objects appear much nearer than they do when the atmosphere is hazy; and this accounts for the sharpness of outline and apparent flatness of objects seen in countries noted for the clearness of the air.

Not only, however, is it found that the lights and shades diminish in intensity as they recede from the eye, but, as a necessary consequence, the contrast between surfaces becomes also less pronounced, and their outlines less distinct, the more the distance is increased. Therefore outlines themselves should vary in the thickness of the lines, and should become fainter and finer as they recede.

Fig. 45 represents an octagonal prism.

Before entering on this study it is necessary to preface it by an elementary geometrical construction, in order to show the reason for the disposition of the lines.

Let A B C D E F G H (Fig. 46) be an octagon of which a perspective view is required.

Now, as in the case of circles, it is necessary that polygons should be enclosed in rectangular figures, and the one which will best contain an octagon is the square formed by producing four of its sides—viz., I J K L.

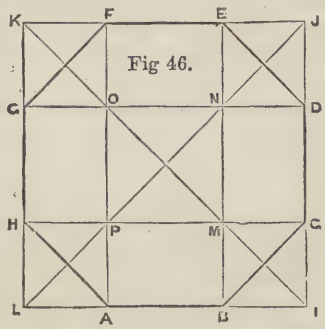


Fig 46.

Draw the diagonals I K and L J, also the lines A F, B E, G D, H C, cutting the diagonals in M, N, O, P.

Put the square I J K L into perspective, and draw the diagonals. Set off spaces l a, i b, as shown in the annexed figure (Fig. 45), corresponding to those lettered L A and I B. From a and b draw lines to the point of sight, cutting the diagonals in m, n, o, p.

Through m, n, o, p draw horizontal lines which will cut the sides i j and k l in c, d, g, h. The points a, b, c, d, e, f, g, h are the angles of the octagon perspectively rendered as lying on the ground-plane with two of its sides parallel, and two at right angles to the picture.

Proceeding now with Fig. 45, it will be evident that, if a plane octagon is contained in a square, *an octagonal prism will be contained in a solid oblong* (called geometrically a *parallelopiped*). In commencing, therefore, to draw the object, sketch this oblong, as shown by the dotted lines which are retained to act as guides, but which may be rubbed out in the drawing when the required figure has been correctly delineated.

In the present group it will be evident that the eye of the spectator is on the right-hand side of the objects, and on a higher level.

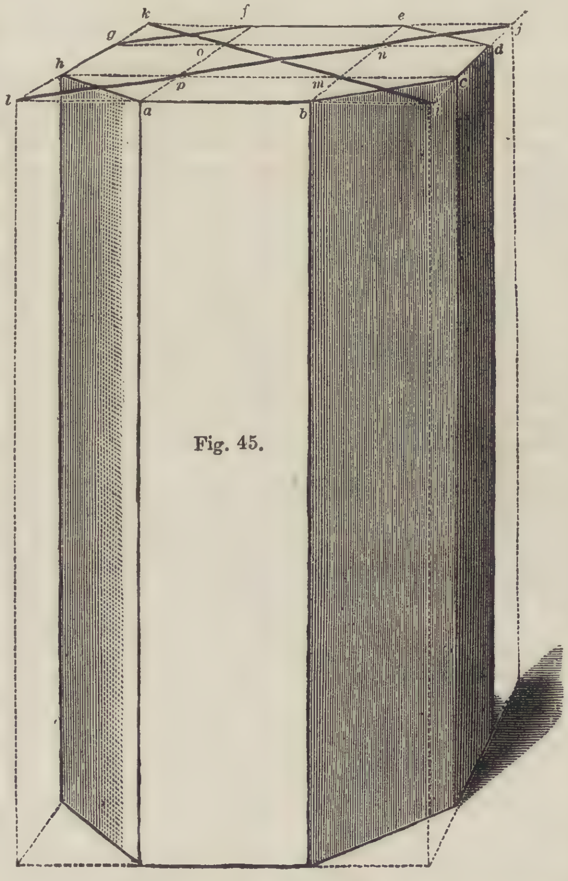


Fig. 45.

The student is advised not to place his models exactly like those in the example, but to adopt the principles laid down, instead of copying the drawing. Assuming, however, that he has the exact models, his view will vary according as his eye is above or below, on the left or right of the group; and in determining, therefore, the position of the point of sight he will be guided by the instructions already given. Having, then, sketched the general form of the oblong block, rendering it as if transparent, the perspective representation of the octagon is to be drawn in the figure representing the square top of the block in the manner already shown in the preceding paragraphs of the present lesson.

From the angles of this figure perpendiculars are to be drawn which will cut the base in corresponding points, and these being joined, the view of the octagonal prism will be completed.

The shading of this object in its present position will be found extremely simple, the principles having already been explained. In accordance with these, since the light is supposed to fall on the front and left side of the prism, they will be fully illumined. The darkest shade will be on the right side, which, being a part of the square block in which the octagonal prism is contained, is at 90° to the picture-plane; whilst the side between this and the front being at only 45°, will be of a lighter tint.

The objects represented in the next figures will possess some interest for carpenters and joiners, since they show the method of drawing pieces of wood which are to be "halved" together; a process which has been described in lessons in "Building Construction." Figs. 47 and 48 show the pieces separately. Out of the upper side of the one and the lower side of the other pieces are cut, the recess being in each case as wide as the wood to be sunk into it, and half as deep; and thus, when the pieces are brought together, the thickness at A fills up the depth of B, and the surface C becomes flush with D; a square mortise is cut through both pieces, for a purpose to be subsequently explained.

In drawing these pieces, no notice is, in the first instance, to be taken of the recesses, but the pieces of wood are to be drawn as if complete. The square end of the lower piece is to be drawn first, and from this the long edges converge to the point of sight, in the manner already explained.

On one side of the square mark E, the depth of the recess, and from E draw a line to the point of sight. Then, having marked F and G, draw horizontal lines across the upper surface, and from the extremity of each draw the vertical lines, as at B, as far as the line E. The rest will be easily understood from the illustration.

In Fig. 48, which is parallel to the plane of the picture, the front is, of course, to be drawn first, of its true proportions, but slightly diminished, in consequence of being placed at a short distance back in the picture, so as to be immediately over the middle of Fig. 47. The upper surface and end of this piece will be drawn as in previous cases; and the recess is next to be drawn, care being taken that it corresponds in width with the line at F. The mortise will be easily drawn without further explanation.

The object formed by the union of the pieces will be a cross, which will be the subject of a subsequent study.

Figs. 49 and 50 are two pieces of wood of the same thickness as Figs. 47 and 48, and making together, including the length of the tenon, the same length as the other two pieces. The tenon on Fig. 50 is flat, that on Fig. 49 is square, and has a space equal to one-third of its width cut away; the tenon on Fig. 50 is exactly equal in width to this space, into which it fits; and thus, in making up the length, only one of the

tenons is counted. When, therefore, the tenon *a* is inserted into the groove *b* the whole piece becomes the length of Figs. 47 and 48, and its purposes will be shown in a future lesson.

The method of drawing these two pieces is precisely the same as that already shown, and therefore no further explanation is deemed necessary.

i j l k for the end of the one bar which is at right angles to the plane of the picture, and from the angles draw lines to point of sight, meeting the distant side of the slab in *m*, *n*, *o*; lines joining these points will complete this bar.

Draw the diagonal *b e*, which will cut the lines *j n* and *i m* in *p* and *q*.

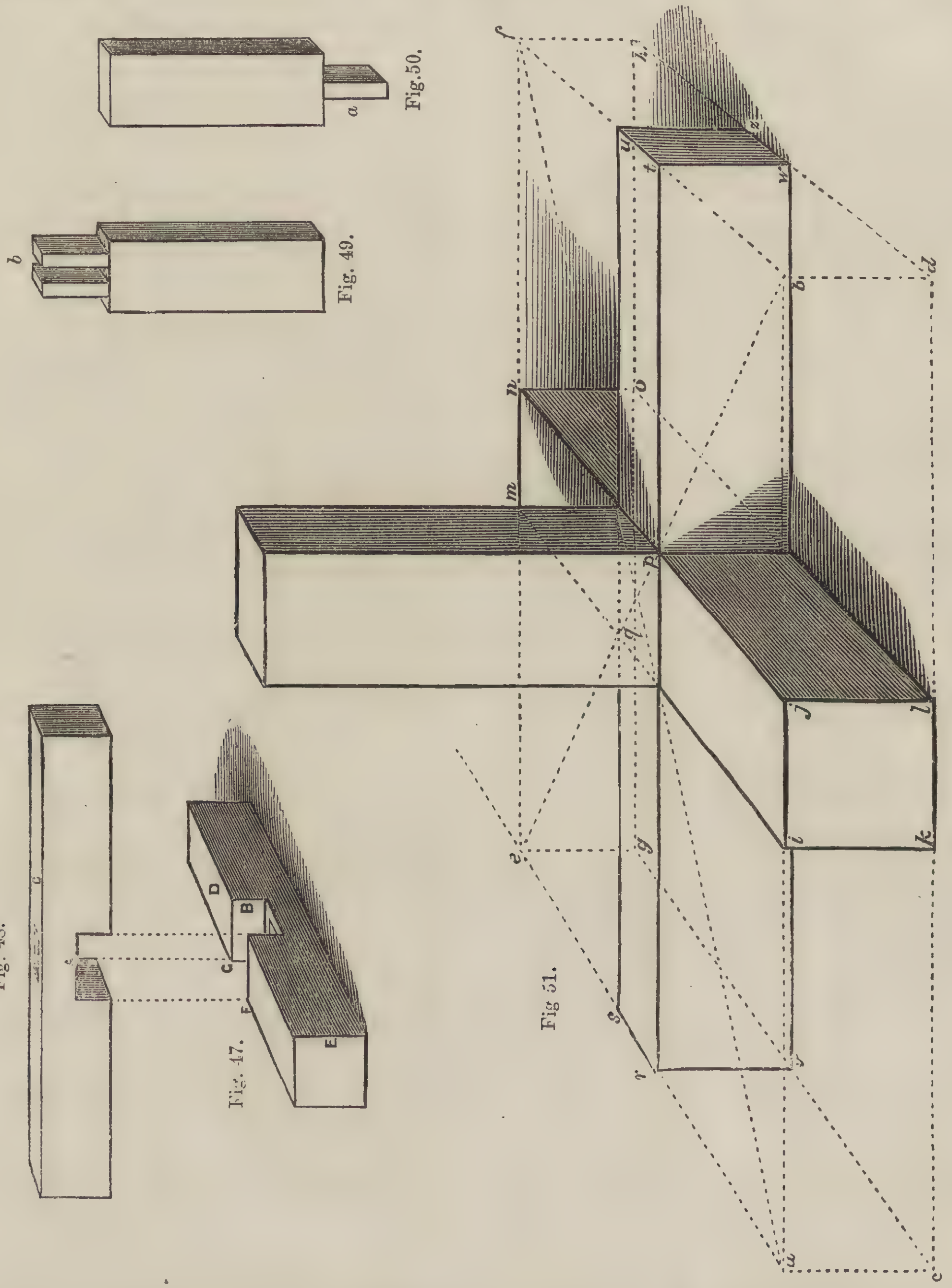


Fig. 50.

Fig. 49.

Fig. 51.

Fig. 48.

Fig. 47.

Fig. 51 shows the cross lying horizontally, and serving as a stand for an upright. This construction is used for a variety of purposes that will readily suggest themselves.

Now it is clear that a cross having four equal arms would be contained in a square slab, and this knowledge shows us the most simple method for drawing the object.

Let *a b d c* be the front edge of such a slab, its length and thickness being those of the wood of which the cross is made.

Complete the view of the block, rendering it as if transparent.

Now, in the middle of the rectangle *a b d c* draw the square

Through *p* and *q* draw horizontal lines, which meeting *a e* in *r*, *s*, and *b f* in *t*, *u*, will give the upper surface of the second bar of the cross. From *p* draw a perpendicular to meet the line *l o*, and this will give the point through which the line *v w* is to be drawn; the lines *r v*, *t w*, and *u z* will then complete the view of the cross.

Now at the points of junction of the two bars raise perpendiculars, and finish the upright, as in Fig. 50.

The shading of this object is exceedingly simple, and will be readily understood on reference to the illustration.

NOTABLE INVENTIONS AND INVENTORS.

XX.—GLASS-MAKING (*continued*).

BY JOHN TIMBS.

A SQUARE solid pedestal of yellow-tinged glass is preserved in the Museum of Economic Geology, in Jermyn Street; it is surmounted by a small lion, carved by the engraver's mandril-tool, at the lathe, at great labour and cost. This was probably made from English glass, re-fused in China with an increased quality of lead. Small coloured vases, figures, and almost every description of ornament sculptured in stone, have been imitated in opaque glass by the Chinese. Yet they neglect the manufacture of useful articles of glass, and re-melt broken glass from Europe for such articles as they require. The Emperor has a royal glass manufacture in Pekin, though it is carried on as much for amusement as for utility.

Glass engraving in its modern acceptation—viz., roughed and polished in intaglio—was, probably, unknown to the Romans and their predecessors. The art of cutting glass in relief was, however, known to them at a very remote period; for which purpose, as we learn from Pliny, the diamond was used.*

Pictures were formed by the ancients laying together fibres of glass of various colours, fitted to each other so exactly, that a section across the fibres represented the object to be painted; and was then cemented by fusion into a homogeneous, solid mass. In some specimens discovered in the middle of the last century the pieces had been so accurately united by intense heat, that not even by means of a powerful magnifying glass could the junctures be discovered. One small fragment, in the British Museum, exhibits an arabesque border of various colours, the outlines of which are well divided and sharp, and the colours pure and vivid; whilst a brilliant effect has been obtained in another piece by the artist employing in contrast opaque and transparent glasses. The pictures appear to be continued throughout the whole thickness of the specimen, as the reverses correspond in the minutest points to the face; so that were the glass to be cut transversely, the same arabesque border would be found exhibited on every section. It is conjectured that this curious process was the first attempt of the ancients to preserve colours by fusing them into the internal parts of the glass. In the British Museum are many of these interesting curiosities of glass mosaic work, some of perfectly white clear glass, in leaves or flowers, on a dark-green ground; most of the pieces are small, and the patterns very minute. There are also numbers of fragments of white enamel upon blue, and white upon amethyst grounds, well executed in relief; probably the work of eminent Roman or Greek artists resident in Rome.

In the British Museum there are a few large cinerary urns of green glass, which are fine specimens of the ancient art of glass-blowing. The round vases are of elegant form, with covers and two double handles, showing that the ancients were well acquainted with the art of making round glass vessels. The most celebrated ancient glass vase is that which was for more than two centuries the principal ornament of the Barberini palace, and which is now known as the Portland vase. It was found about 1560, in a sarcophagus under the Monte del Grano, two miles and a half from Rome, on the road to Frascati. It was deposited in the palace of the Barberini family until 1770, when it was purchased by Byres, the antiquary, and sold by him to Sir William Hamilton, of whom it was bought, for 1,800 guineas, by the Duchess of Portland, at the sale of whose property it was bought in by the family for £1,029. The vase is 9¾ inches high and 7¼ inches in diameter, and has two handles. It is of glass: yet Breval considered it chalcedony; Bartoli, sardonyx; Count Tetzi, amethyst; and De la Chausse, agate. It is ornamented with white opaque figures upon a dark-blue semi-transparent ground; the whole having been originally covered with white enamel, out of which the figures have been cut, like a cameo. The glass foot is distinct, and is thought to have been cemented on after bones or ashes had been placed in the vase. The seven figures, each five inches high, are said by some to illustrate the fable of Thaddeus and Theseus; by Bartoli, Proserpine and Pluto; by Winckelmann, the nuptials of Thetis and Peleus; Darwin, an allegory of Life and Immortality; others, Orpheus and Eurydice; Fosbroke, a marriage, death, and second marriage; Tetzi, the birth of Alexander Severus, whose cinerary urn the vase is thought to be; while Mr. Windus, F.S.A., in a work published 1845, considers the scene as a love-sick lady consulting Galen. The vase was engraved by Cipriani and Bartolozzi in 1786: copies of it were executed by Wedgwood, and sold at fifty guineas each, the model for which cost 500 guineas; there is a copy in the British and Mediæval Room.

The Portland vase, February 7, 1845, was wantonly dashed to pieces with a stone; but the pieces being gathered up, the vase has been restored by Mr. Doubleday so beautifully, that a blemish can scarcely be detected. A drawing of the fractured pieces is preserved.

This beautiful work of art affords satisfactory proof that the manufacture of glass was carried to a state of high perfection by the ancients. Sir Joseph Banks and Sir Joshua Reynolds bore testimony to the admirable execution of Wedgwood's copies of the vase, which were chased by a steel rifle after the bas-relief had been wholly or partially fired.

Venice, during a long period, excelled all Europe in the fineness of its glass. In the thirteenth century the processes of the Phœnicians seem to have been learnt by the Crusaders, and transferred to Venice and the neighbouring island of Murano, where they were long held secret, and formed a lucrative commercial monopoly. The old Venetian blown glass was light, bright, vitreous in appearance, stained with the richest possible colours. Some of the particular secrets of this manufacture have been handed down from father to son, and so carefully treasured up, that at this very day, quite as much as in the age of Marco Polo, Venice possesses the absolute monopoly of the art; and lineal descendants of the old Venetian glass manufacturers still inhabit the island of Murano.

The revival of the ancient art of glass-blowing is due to Dr. Salviati, whose imitations of the old Venetian *soffiati* and execution of new designs are most successful. The *soffiati*, or blown glass, produced by Dr. Salviati, equal, and even surpass, the old in lightness, brilliancy, colour, and design. The glass-blowers of Murano are now able to produce nearly all the famous kinds of ware so peculiar to Venetian glass.

First, and most characteristic, of the Venetian varieties is the *Laticinio* or filigree glass, with coloured threads, generally in opaque milk-white; hence the name *Laticinio*. In some specimens the threads form lacework glass, or *Vitro di Trino*. The *reticello* is produced by a kind of network, consisting of small bubbles of air inclosed within the mass, and arranged in a regular series, crossing and interlacing each other. The *filigree* glass is produced by using rods which contain threads of white or coloured enamel in a body of clear glass. The *millefiore* consists of a mass of clear white crystal, inside of which and embodied in it are representations in coloured glass of coral flowers, and is formed by laying together fibres of glass of various colours. Winckelmann describes a similar art of the ancients. The *ritorto*, or twisted patterns, or many coloured glass rods, are fused together with clear glass. *Schmelze* is a semi-opaque glass, of a richly variegated brown, green, or blue; and *Avanturine*, with metallic filings of levigated leaf gold suspended in it, is said to have had its origin in a workman having accidentally let fall some brass filings into a crucible of melted glass, whence both the process and the term.

The celebrated frosted or "crackle" glass of the Venetians was long considered a lost art; it is made by suddenly plunging the hot glass into cold water, and in this manner fractures are produced of a crystalline character. The glass is then re-heated

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* To Dr. Wollaston are we indebted for this explanation of *how the diamond cuts glass*. He ascertained that the parts of the glass to which the diamond is applied are forced asunder, as by a wedge, to a most minute distance without being removed, so that a superficial, continuous crack is made from one end of the intended cut to the other. After this, any small force applied to one extremity is sufficient to extend this crack through all the whole substance, and across the glass; for since the strain at each instant in the progress of the crack is confined nearly to a mathematical point at the bottom of the figure, the effort necessary for carrying it through is proportionally small. Dr. Wollaston found by trial that the cut caused by the mere passage of the diamond need not penetrate so much as the two-hundredth part of an inch. He found also that other mineral bodies recently ground into the same form, are also capable of cutting glass, but they cannot long retain that power, from want of the requisite hardness.

Coke possesses one of the remarkable properties of the diamond—that of cutting glass so clean and perfect as to exhibit the most beautiful prismatic colour, according to the perfection of the incision.

at the furnace, and the heated ball is afterwards expanded by blowing. Although frosted glass appears covered with fractures, it is perfectly sonorous.

The Venetians, besides discovering the art of rendering glass colourless by means of manganese, also enjoyed the monopoly of mirrors, the silvering of which was a secret long kept from other countries; but foreign competitors now produce larger plates.

Venice still possesses the absolute monopoly of the art of bead-making; and great impetus has been given to the bead trade by the prevailing fashion of black beads, for which there is a great demand; as also for glass bugles, of which vast quantities are sold for the African and other foreign markets. The manufacture is divided into common glass beads and enamel beads. The furnaces are built of fire-clay. The materials are vitrified in pots, the principal ingredients for glass beads being Nola sand, Catania soda, natron, antimony, arsenic, manganese, minium, nitre, etc. The materials for enamel beads are almost every product of the mineral kingdom; gold and silver being used in considerable quantities. The Venetians are still in possession of the best enamel processes—the inlaid or marqueterie mosaics produced by all the enamel pieces perfectly united, generally used for ear-rings, bracelets, etc. The Florentine mosaics are made up of stones; the Roman of thin pieces of enamel; and the monumental or Byzantine are most fitted for architectural decorations. In England, fine specimens of modern Venetian mosaics may be seen at the South Kensington Museum, and St. Paul's Cathedral, London. The vaulted roof of the Wolsey Chapel, at Windsor, represents the kings and queens of England in mosaic, and Dr. Salviati executed mosaics for the national memorial to the late Prince Consort in Hyde Park. Enamels are much more permanent than any other substance that has been used in the composition of mosaic, whether stone, marble, or clay, on account of their less porous and less dilatable body.

Gold and silver enamels are now used with improved effect in monumental mosaics, in which the gold or silver is attached to the glass by the action of fire, and the three layers being fired together, form a homogeneous body, which serves to protect the metal for ever against all injury, either by atmospheric action, dust, gas, smoke, or insects, so as not to lose any of its brilliancy or colour, even after many centuries of exposure.

The manufacture of glass was probably introduced into France at the same date as into Germany. Both countries derived their knowledge of it from the Romans; or, probably, from their commercial intercourse with the East, improved by the Romans, and still further advanced in quality and artistic ornamentation, adopted from the Venetians. Later, France sought to increase the supply of her own demands. Her government early decreed that none but gentlemen should engage in any of its branches; and late in the seventeenth century the French glass-blower might be seen laying aside his cocked hat, dress-coat, and sword, to prepare for his daily work.

MINING AND QUARRYING.—XII.

BY GEORGE GLADSTONE, F.C.S.

IRON.

ROLLING—PUDDLED BAR—FINISHING—PROPERTIES OF IRON—GALVANISED IRON—EFFECT OF TIN AND COPPER—NATURAL AND ARTIFICIAL SALTS OF IRON—THEIR USES.

THE final steps in the manufacture of malleable iron consist in rolling, for which purpose there are required two series of rolls, the *roughing* and the *finishing*.

They consist of cylinders of hard iron working in pairs, the grooves in the upper corresponding exactly with those of the lower, as shown in Fig. 17. The latter are turned by a crank connected with the shaft A A, and the upper series necessarily revolve in the opposite direction at the same rate, being driven by the cog-wheels B, B. The space between the cylinders can be slightly modified by turning the screws C C, which connect, through the bearers, with the upper rolls. The "bloom," or hammered ball, while yet hot, is held by a pair of tongs, and pressed by the first workman against the largest groove in the rolls, which, as they revolve, draw it in between them, the surface of the grooves being slightly roughed by scorings like those of a file, so as to take firm hold of the iron. It thus becomes elongated, and takes the form of a rod. The second workman, on the other side of the rolls, lays hold of it, as it passes through, with another pair of tongs, and hands it back again, and so on until the iron has passed through the whole set of grooves, down to the smallest. When it has gone under the flat rolls it takes the form of a flattened bar of iron, and is known by the name of "puddled bar."

The processes of hammering and squeezing, described in the last article, and the subsequent rolling, have still further improved the quality of the iron, though again at the expense of quantity. The sample of iron which was described in detail in Article X., and contained at the end of the puddling 0·772 per cent. of carbon, and 0·168 per cent. of silicon, contained, after rolling, only 0·296 per cent. of the former, and 0·120 per cent. of the latter. The hammer slag or mill scale which comes off during these processes contains, however, a good deal of iron, and is of value in puddling, so that the metal is not ultimately lost. It consists, indeed, entirely of the protoxide and sesquioxide, containing 70 to 75 per cent. of metallic iron.

Puddled bar is still capable of improvement; and for making the best descriptions of iron it is cut up into short lengths by means of massive shears driven by steam, made up into piles or fagots, and then put into the re-heating furnace, after which it is again rolled. This operation is repeated as often as may be desired; the more the iron is worked in this way the better being the fibre. The piles are sometimes made by laying the alternate pieces of iron crosswise, the intertwining of the fibre being supposed to be more complete when this is done. At other times an inferior quality of iron is put in the middle of the fagot, so that when rolled out again the exterior of the bar shall be of superior strength to the interior; this is not unfrequently done as a matter of economy in the manufacture of railway bars, as the principal wear and tear is upon the head of the rail, and there is no occasion to waste the best iron upon those parts which are sure to outlast the upper surface.

The re-heating furnace is constructed on the reverberatory principle, and coal is generally used as the fuel. The hearth upon which the fagots are laid is made of sand, and slopes down towards the flue, so that whatever iron passes into combination with the silicon shall at once flow down to the tap-hole. The air is excluded as far as possible, so as to prevent oxidation, and the iron is taken out immediately it has arrived at a welding heat. It is then in that sticky stage so peculiar to iron, which renders it so easy of manipulation, and on passing through the rollers the several pieces become perfectly united.

The finishing rolls, which are now used, are quite smooth, and the groovings in them are made to conform more and more to the size and form which the iron is ultimately to assume, until the last pair of grooves will turn it out of the precise pattern required. In this way all the different forms and sizes of merchant iron—bar, rod, sheet, rails of various patterns, T and angle iron, etc.—are produced. The rate at which the rolls are driven varies very greatly according to the nature of the work in hand; for ordinary purposes, sixty to eighty revolutions per minute will be made, so that the iron has passed through the whole series of grooves, and comes out finished before it has had time to cool. The cylinders themselves are supplied with a little stream of cold water, in order to prevent them from becoming overheated.

As illustrations of what different kinds of work are done by the rolling mills, we may refer to "slit rods," which are used for nail-making and such-like purposes. In the slitting mill a thin bar of iron is at once cut into a number of very narrow slips, the one roller having deep and narrow grooves very close together, and the other collars to correspond, made with sharp cutting edges. By way of contrast, let us now take the manufacture of armour plates. They are sometimes made in the forge, but at other works they are rolled out. Instead of a strip, a quarter of an inch or less in diameter, the rolls have now to turn out a plate of iron perhaps twelve inches thick and some six feet wide, weighing many tons. Such plates have been turned out at the works of John Brown and Co. (Limited), at Sheffield, where the armour for many of our iron-clad floating batteries has been made. The process employed is essentially what has been already described, but the difficulty of the operation increases with the accumulation of mass, as it is difficult, even with the most powerful machinery, to bring sufficient force to bear to weld the component pieces perfectly together.

The workmanship is, however, so good, that on the edges being planed there are no indications to the eye of any want of coherence.

The peculiar property of iron called "welding" has not, however, yet received all the consideration it deserves. It has been mentioned in the manufacture of the better qualities of finished iron, and the making of all large pieces of rolled iron is absolutely dependent upon it. Equally so is this the case in making large forgings. Some of the largest armour plates have been forged with the steam-hammer, one of thirteen tons weight made in this way having been on view at the International Exhibition of 1862. These are built up of separate pieces of iron raised in the furnace to a welding heat, and then hammered into one solid mass. This is an operation which cannot be accomplished with any other of the useful metals, and is principally due to the circumstance that iron (unlike all the rest), when heated, does not pass suddenly into the molten state, but after becoming red hot, at which stage it commences to soften sufficiently to yield to the hammer, can be raised to a much higher temperature and almost to a white heat without melting. At this stage the presence of a little flux will remove any oxide that would otherwise form on the surface of the iron; and the metal itself being then in a pasty or sticky condition, the clean surfaces of any pieces coming in contact will readily adhere to one another, while by pressure or hammering they may be brought into absolute contact throughout their mass, forming a single piece of solid iron.

The shafts of marine engines and all other large pieces of machinery which have to bear much strain, must be forged, not cast. That of the *Great Eastern* weighs something more than thirty-one tons, made up of bars welded together under the steam-hammer. Cast iron, in cooling, takes an irregular crystalline form, and the parts do not cohere with any great tenacity, so that all the products of the foundry are comparatively brittle. The finishing processes impart fibre to the iron, by which its strength is very greatly increased. The difference in the structure of the iron is very different when broken, the one breaking off short and presenting a granular appearance, while the other is more or less drawn out into threads. This is one of the best tests that can be applied, and it is therefore constantly adopted. If the iron is of the very finest quality, a thick round bar of it may be tied into a knot when cold without breaking, whereas an inferior iron is certain to give way. Hammering iron when cold is believed to have the opposite effect, and the sudden breaking of iron after having been subjected to a jarring or vibratory action for a long time, is considered by some to be due to a molecular change in the particles of the iron. The brittleness of iron during extreme cold weather is probably to be attributed rather to the unequal contraction of the parts most exposed.

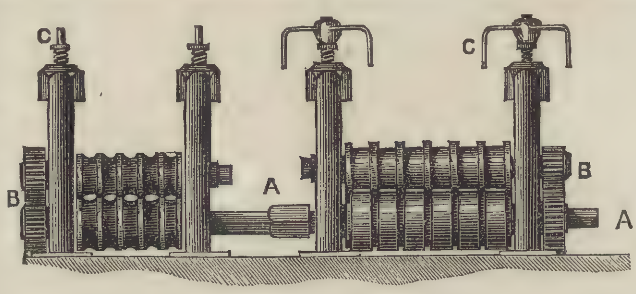


Fig. 17.

Iron suffers under one disadvantage more than almost any other metal—viz., the tendency to rust. Whenever exposed to the influence of a moist atmosphere, an oxidation of the surface is sure to take place, and the iron commences to be eaten away. When once this action has set in it is difficult to arrest its progress altogether, and therefore, wherever possible, the ironwork should be coated with paint, or some other article impervious to the air, without delay. Those portions of machinery which must necessarily be kept bright are best protected by being carefully smeared with grease.

It has been found, however, that zinc has the property of retarding the oxidation of iron, and this has led to a very extensive manufacture of what is called "galvanised iron," which has recently been largely employed for roofing purposes. The iron is rolled out into thin sheets, and the surface is thoroughly cleaned by being exposed to the action of a weak acid and then washed, when it is said to be "pickled," after which it is immersed in a bath of melted zinc to which some ammonia is added. On withdrawing the sheets of iron after a time from the bath, a thin layer of zinc will be found adherent to the entire surface, which has so combined with the iron that it cannot be again removed. Iron wire rope for the rigging of ships, etc., chains, and other articles much exposed to the influences of the weather, are very often coated with zinc in the same way.

Both tin and copper seem to exercise an opposite effect. It will be familiar to most housewives how rapidly a tin plate will be covered with spots of rust wherever the coating of tin has been accidentally removed and the iron which forms the foundation becomes exposed to the air. A further description of tinned iron will be given when we come to speak of the reduction and uses of tin, the latter being the metal which imparts to these plates their principal value. The effect of copper upon iron, especially in the presence of sea-water, is so marked, that copper sheathing cannot be applied to an iron vessel, and even in the highest classed wooden ships iron bolts are not allowed to be used below the level of the coppering. Iron vessels, which are now becoming such great favourites (especially in the steam trade), have, therefore, to be coated with some paint or varnish; but as yet no compound has been hit upon which satisfactorily fulfils all the purposes desired.

It seems hardly right to leave the subject of iron, which has now been traced from its ores through all its varied stages up to the manufactured article, without referring to sundry chemical compounds of iron, both natural and artificial, which are of much value in the arts.

Sulphide of iron is a very common mineral, frequently called iron pyrites, which is principally wrought for the sake of the sulphur and not the iron; and as to which it will therefore be sufficient to refer the reader to the article on the manufacture of sulphuric acid ("Chemistry applied to the Arts," No. XI.).

The red and brown hæmatites (the anhydrous and the hydrated sesquioxides of iron) have been incidentally mentioned as furnishing rouge and ochre respectively. The latter is an article of some commercial importance. Chrome iron ore is also principally valuable as the source of chromic acid, which enters largely into the composition of yellow paints and dyes. There are also various ores of iron of which the other ingredients form the most important feature, and which will have to be referred to when treating of the respective metals.

The artificial compounds of iron are of considerable importance in the arts. There is the sulphate, more generally known under the name of copperas or green vitriol, which is made by dissolving iron filings in dilute sulphuric acid, and then evaporating the solution down until the salt crystallises out; or as a bye-product in the manufacture of alum, which is the ordinary commercial article. It is largely used in dyeing black and in making black ink, that colour being produced by the action of this salt upon any article containing tannic or gallic acid.

Iron also enters into the composition of Prussian blue (ferrocyanide of iron), and into the yellow and red prussiates of potash, all of which are largely used by dyers. Acetate of iron is also employed for producing a deep black colour with madder. It is prepared by dissolving small pieces of iron in warm acetic acid.

The use of iron in medicine is also fully recognised. Various artificial combinations of it are in constant use in pharmacy, some two dozen different preparations of this metal appearing in the Pharmacopœia; besides which, it is drunk largely in mineral waters, all the chalybeated and many of the other celebrated springs of this country and the Continent containing notable quantities of the salts of iron.

We have reserved for the next article all reference to a very important modification of iron, steel being a subject of sufficient magnitude to be treated separately, and which has characteristics of its own which will come out more clearly by being considered as a distinct subject.

APPLIED MECHANICS.—XVIII.

BY ROBERT STAWELL BALL, M.A., LL.D.,

Astronomer-Royal for Ireland.

MACHINERY USED IN THE SPINNING OF COTTON.

It will be our duty in the present lesson to indicate as fully as our limits will admit the principles of the different machines which are used in the cotton manufacture. We must trace the history of the fibre from its first separation from the seed which it invests to its final conversion into yarn. We cannot profess to do more than point out and explain the principles upon which the different classes of machines act. Whole treatises are extant upon the different branches of the manufacture, to which those must be referred who desire to follow the subject into details. In Ure's "Dictionary of Arts, Manufactures, and Mines" will be found a very copious and valuable article on the subject of the cotton manufacture, of which we would recommend the perusal to those who wish to study the subject more fully.

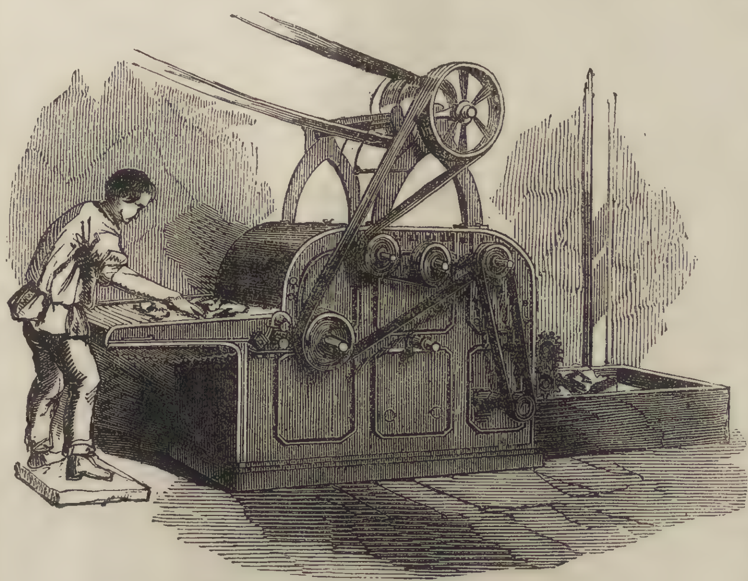
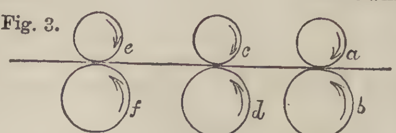


Fig. 1.—COTTON CLEANING MACHINE.

The cotton-fibre, as it is gathered from the plants which produce it, is firmly attached to the seeds. The first operation consists in detaching the fibre from the seeds by the process of "ginning," as it is called. The most improved machine for this purpose is one which simulates as far as possible the action of the finger and thumb, which would be naturally employed in detaching the cotton from the seed. The ordinary forms of gin are of a simpler construction: one of those most usually employed is termed the "saw-gin." A circular saw, furnished with teeth of peculiar construction, works through a slit in a table; upon the table the cotton to be ginned is placed; the fibres of the cotton are severed by the teeth and drawn through the slit, leaving the seed behind which is too large to pass through the slit. A number of these saws are attached together upon a roller, the slits forming a sort of grating, upon which the cotton is supplied. In proximity with the saw is a cylindrical brush, which revolving against the saw-teeth detaches from them the fibres of cotton which have been operated upon. The fibres of cotton are somewhat injured by the action of the saw-gin, hence the more improved machines which have been referred to have been introduced.

Fig. 2.

Fig. 3.



After the cotton has been detached from the seed it is packed in bales, the necessary compression being generally produced with the aid of an hydraulic press. In this state it is delivered to the manufacturer.

In the hands of the manufacturer the first operation to which the cotton is subjected is that of cleansing. The machine which is used for this purpose is called a "willow" (Fig. 1). The willow consists of a hollow cylinder fitted with spikes internally. The cotton placed in this cylinder is shaken about, and much of the dirt falls out through a grating at the bottom of the cylinder. In this process also many of the larger flocks are opened and loosened, so that the subsequent operations are facilitated. A machine used in the cleaning of cotton is shown in the above cut. The workman puts in the foul cotton at one end, and after being exposed to a winnowing action in the machine it is delivered in a clean state.

The various operations necessary for cleaning and opening the cotton having been accomplished, the next stage is the very important process of carding. The fibres of the cotton as they leave the blowing machine are bent and convoluted, and lying in all directions: the operation of carding consists in placing them uniformly side by side.

The action of a pair of cards can be understood from the accompanying diagram. A, B (Fig. 2) are portions of a pair of cards. The wires are bent in the way shown in the figure. Let us now suppose a flock of cotton to be placed between the two cards, and let the cards be moved in the directions shown by the arrows. The teeth of the cards will regularly comb out the cotton, each tooth will take upon it one or more loops of the fibres, and make the two ends of the fibre which form the loop lie parallel to the direction of motion. As the process proceeds the tendency will be for one side of the loop to be drawn over to the other, and thus the fibres will be placed in parallel lines.

The cards are generally mounted on a large cylinder, against a part of the circumference of which the opposing cards are held.

After the process of carding has been completed, the cotton is in a fleecy layer, and the operation of drawing and doubling is necessary, in order to prepare for spinning. This operation places the fibres more strictly parallel than they have been left by the carding, and consolidates the fleecy mass. As the operation of drawing introduces a fundamental principle in the whole cotton manufacture, we shall enter into some detail on the subject. We shall first quote an account of the machine which is given in Ure, and then we shall describe the theory of the action with the aid of mathematical symbols.

"Let a and b (Fig. 3) represent the section of two rollers lying over each other, which touch with a regulated pressure, and turn in contact upon their axes in the direction shown by the arrows. These rollers will lay hold of the fleecy riband presented to them at a, draw it between them, and deliver it quite unchanged. The length of the piece passed through in a given time will be equal to the space which a point on the circumference of the roller would have described in the same time; that is, equal to the periphery or circumference of one of the rollers multiplied by its entire number of revolutions.

"The reader will readily understand that the same thing holds with reference to the transmission of the riband through a second pair of rollers c, d, and a third e, f. Thus the riband issues from the third pair of rollers exactly the same as it entered at a, provided the surface speed of all the rollers be the same; but if the surface speed of a and b be less than that of c and d, the consequence can be nothing else in these circumstances than a regulated drawing or elongation of the riband in the interval betwixt a b and c d, and a condensation of the filaments as they glide over each other to assume a

straight parallel direction. In like manner the drawing may be repeated by giving the rollers e, f a greater surface speed than that of the rollers c, d. This increase of velocity may be produced either by enlarging the diameter or by increasing the number of turns in the same time, or finally by both methods conjoined. In general the drawing machine is so adjusted, that the chief elongation takes place between the second and third pair of rollers, while that between the first and second is but slight and preparatory. It is obvious besides that the speed of the middle pair of rollers can have no influence upon the amount of extension, provided the speed of the first and third pair remains unchanged. The rollers a, b, c, d maintain towards each other continually the same position, but they may be removed with their framework more or less from the third pair e, f, according as the length of the cotton staple may require. The distance of the middle point from b and d, or its line of contact with the upper roller, is, once for all, so calculated that it shall exceed the length of the cotton filaments, and thereby that these filaments are never in danger of being torn asunder by the second pulling while the first holds them fast. Between d and f, where the greatest extension takes place, the distance must be as small as it can be without risk of tearing them in that way, for thus will the uniformity of the drawing be promoted. If the distance between d and f be very great, a riband passing through will become thinner or perhaps break in the middle, whence we see that the drawing is more equable the shorter is the portion submitted to extension at the time, and the nearer the rollers are to each other, supposing them always distant enough not to tear the staple. The under rollers b, d, f are made of iron, and to enable them to lay firmer hold of the filaments, their surfaces are fluted with triangular channels parallel to the axis. The upper rollers a, c, e are also made of iron, but they are smooth and covered with a double coating, which gives them a certain degree of softness and elasticity: a coat of flannel is first applied by sewing or glueing the ends, and then a coat of leather in the same way. The junction edges of the leather are cut slanting, so that when joined by the glue (made of isinglass dissolved in ale) the surface of the roller may be smoothly cylindrical. The top rollers are sometimes called the pressers, because they press by means of weights upon the under ones. A bar of hard wood, whose under surface is covered with flannel, rests with merely its own weight upon the top rollers, and strips off all the loose hanging filaments."

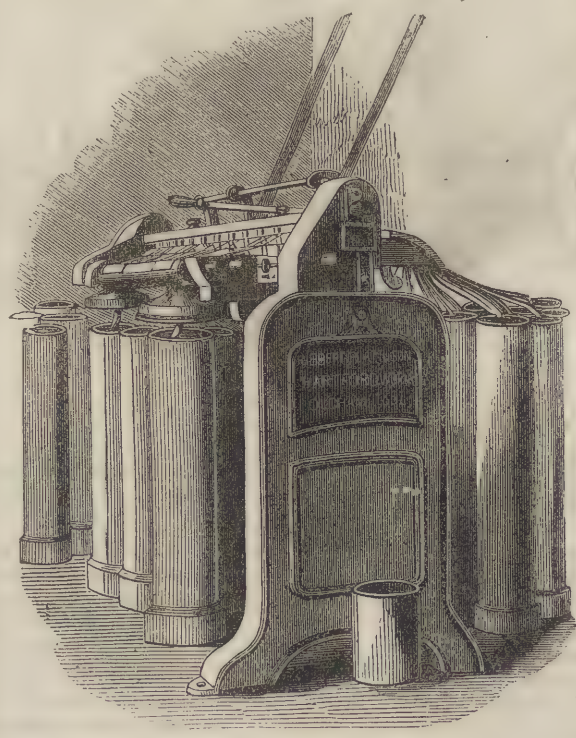


Fig. 4.—THE DRAWING MACHINE.

Were the drawing of a riband continued till all its fibres attained the required degree of parallelism, it would be apt from excessive attenuation to tear across. The dilemma is got rid of in a very simple way—namely, by laying several ribands together at every repetition of the process, and incorporating them by the pressure of the rollers. The practice is called "doubling." The drawing machine is shown in Fig. 4.

Let x, y, z be the diameters in inches of the three rollers which are driven by the shafting of the mill; the other rollers of the drawing machine are moved by being in contact with x, y, z. Let these rollers make l, m, n revolutions per minute respectively; then since the circumferences of the rollers are

$$\frac{22}{7}x, \quad \frac{22}{7}y, \quad \frac{22}{7}z,$$

the number of inches each circumference moves over in one minute is

$$\frac{22}{7}x \times l, \quad \frac{22}{7}y \times m, \quad \frac{22}{7}z \times n.$$

We shall now proceed to express in terms of these quantities the length which one foot of the riband of adhering cotton filaments attains after having passed through the drawing-frame.

In the space of one minute the second pair of rollers have delivered a length of riband represented by

$$\frac{22}{7}y \times m,$$

and therefore it is clear that the length of riband

$$\frac{22}{7}x \times l$$

which was delivered by the first pair of rollers has been lengthened in passing through the second pair by the amount

$$\frac{22}{7}y \times m - \frac{22}{7}x \times l;$$

therefore the proportion of elongation to the original length is

$$\frac{\frac{22}{7}y \times m - \frac{22}{7}x \times l}{\frac{22}{7}x \times l} = \frac{ym - xl}{xl}.$$

Hence the foot of riband delivered to the first pair of rollers becomes after passing the second pair

$$1 + \frac{ym - xl}{xl} = \frac{ym}{xl};$$

after passing the third pair of rollers this length becomes

$$\frac{ym}{xl} \times \frac{zn}{ym} = \frac{zn}{x}.$$

Thus, as we have already pointed out, the ultimate length is completely independent both of the size and rate of revolution of the middle pair of rollers.

To take an example, we shall suppose x, y, and z to be in the proportions of the numbers $4 : 4 : 5$, and l, m, n to be in the proportions of $4 : 7 : 16$.

Then we have—

$$\frac{zn}{xl} = \frac{5 \cdot 16}{4 \cdot 4} = 5.$$

Thus each foot of the cotton "sliver," as it is called, is drawn out to a length of 5 feet. If the process of doubling and drawing be repeated five times, the total elongation of one foot of original sliver will be

$$5 \times 5 \times 5 \times 5 \times 5 = 3125.$$

The attenuation which would be produced by this drawing is counteracted by the process of doubling, as already explained.

The next process in the manufacture is the first stage of spinning proper, which is accomplished by means of what is known as the "bobbin and fly-frame." We cannot do more than indicate the principles upon which this machine acts, as its mechanical details are of very great complexity. The drawing machines have already attenuated the sliver to such an extent that any further elongation would make it fall asunder. What holds the sliver together is the coherence between the parallel fibres due to the microscopic hooks with which cotton is furnished. Now if we can bring the fibres into more intimate contact with each other, these minute hooks will have more points of attachment to avail themselves of, and the sliver will have increased tenacity: to give the increased proximity, the sliver receives a twist. The effect of this can be readily understood from the homely process of wringing wet clothes. The effect of the twist in wringing the clothes is to bring the fibres of the cloth into such close contact, that the interstices in which the water lurked become obliterated, and therefore the water is expelled. Precisely similar is the action of the twist in spinning. When the fibres are in the untwisted sliver, they

have but few points of intimate contact with their neighbours, and consequently the tenacity is small. The twist immediately brings them into intimate contact, and the tenacity is consequently increased to a surprising extent.

This principle is utilised in the following way. The bobbin and fly-frame is essentially a machine which first draws the sliver like the drawing-frame, only to a greater tenuity, and then on the emergence of the sliver from the rollers gives it a turn or twist sufficient to make it hold together firmly. The twist should not at this stage be greater than that necessary to impart the requisite tenacity; a greater amount would interfere with the subsequent processes. The contrivance by which the twist is given is very ingenious. It will be sufficiently understood from the accompanying figure. A D (Fig. 5) is a vertical spindle receiving motion from the pulley K. At the top of the spindle are the two arms C and D; one of them is hollow, and receives the sliver from the drawing rollers through the orifice O; the sliver passes down through D, and is wound upon the bobbin E. The bobbin receives motion from the pulley H, quite independently of the motion of the spindle.

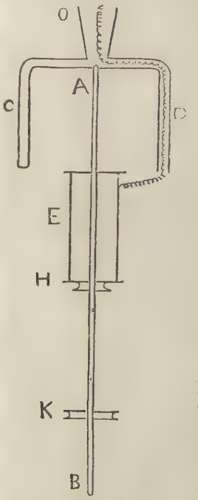


Fig. 5.

If the spindle and the bobbin revolved with the same velocity the roving would receive a twist, but it would not be wound upon the bobbin. If, however, the bobbin have a slightly greater velocity than the spindle, then the roving will, besides receiving a twist, be wound upon the bobbin at a rate due to the difference. The bobbin must, however, receive a motion up and down the spindle in order that the roving shall be wound uniformly along the whole length. Another point has also to be attended to in designing the mechanical arrangements for the motion of the bobbin. As the bobbin gets filled, the successive coils of roving have a larger diameter. If, therefore, the bobbin continued to rotate uniformly the roving would be stretched or torn when the bobbin had received one or two coils: its velocity must, therefore, receive a diminution at the completion of each layer on the bobbin.

TECHNICAL DRAWING.—XLIV.

DRAWING FOR MASONS.

It has frequently been the case that when in course of conversation with an artisan I have urged on him the necessity of acquiring a knowledge of drawing as a means of procuring him advancement in his calling, and as being sure to render him a more highly skilled workman than he could ever hope to become without it, I have been met by the objection that he "had no gift for such work, and could never expect to make any hand of it." His meaning was that he had no natural talent for drawing, and could never hope to excel as a draughtsman.

I have no doubt that such a notion as this deters many a man from endeavouring to reap benefit from our lessons in Technical Drawing. It is, however, a mistaken one, and one which I trust a word in season will remove from the mind of any carpenter, mason, blacksmith, or any one engaged in the constructive arts who may be hesitating on this account, and set him to work at once without further delay. That a natural taste and talent for drawing are necessary to any one who desires to achieve fame in the higher walks of art is indisputable; but as far as elementary drawing needful to help a man in the pursuit of his calling is concerned, it may be learnt as readily as writing. I must now turn to the main subject, and commence the present lesson with a few words on

PROJECTION.

Sections of Cylinders.—Let us now revert to the subject of sections, the importance of which has already been pointed out.

In this lesson the method of obtaining various sections of a cylinder is given. The subject of the projection of cylinders and their sections has been treated of generally in the lessons in "Projection," and it is proposed to extend that instruction in the present lesson.

Let Fig. 405 be the plan of the cylinder, and Fig. 406 the side elevation when placed on an inclined plane.

To draw this elevation, it must be understood that it is the *side* view of the cylinder, viz., that which would be obtained by looking at it in the direction of the arrow shown in Fig. 405; the line A B projected from the diameter will then represent the width of the cylinder, the centre being represented by the point C.

Having drawn at a (Fig. 406) a line at an angle to the intersecting line corresponding with that of the inclined plane, set

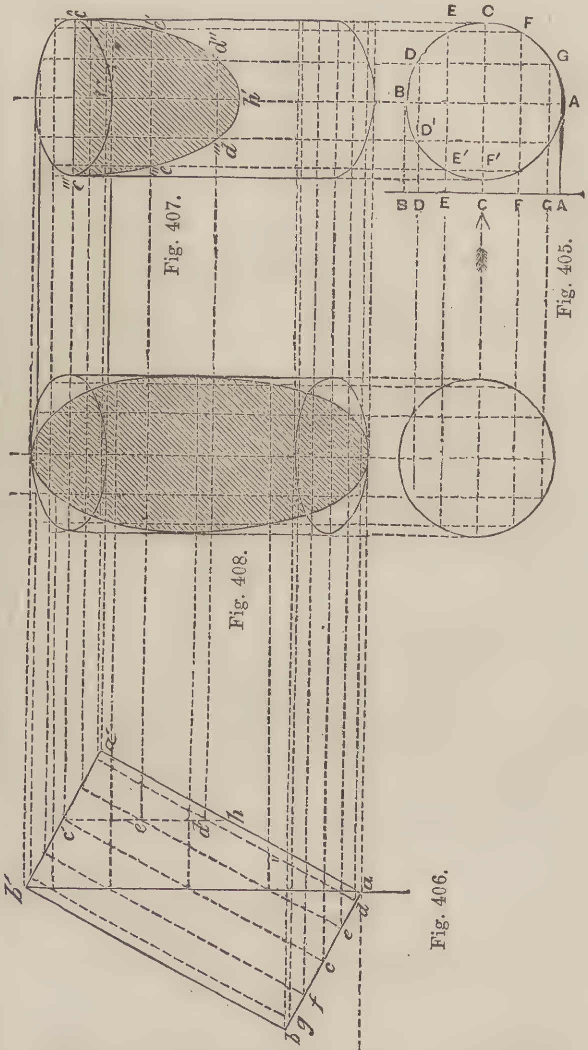


Fig. 407. Fig. 405. Fig. 408. Fig. 406.

off on it a, c, b, draw lines at right angles to a, c, b, and terminate these at the required height by a line a' b', which will complete the general elevation of the cylinder. This would not, however, be sufficient for the projection of a front view of the cylinder; it is therefore necessary to find more points through which the curves may be drawn.

Therefore, divide the plan (Fig. 405) into any number of equal parts, and project these points upon the line A B, viz., D, E, F, G. It must, however, be borne in mind that these letters, as well as C, represent *two* points each: for example, E represents E′ and E *the point beyond*; that is, the point lying immediately behind E′, and therefore hidden by it. Set off these points on a b (Fig. 406)—viz., d, e, f, g—and draw lines from them at right angles to a b, the line c c' being the projection of the axis.

Now from the various points in the plan draw perpendiculars, and from those corresponding with them in Fig. 406 draw horizontals, which, intersecting, will give the points through which the ellipses forming the projection of the two ends of the cylinder are to be drawn: these being joined by perpendicular lines will complete the front view (Fig. 407).

projection (Fig. 407), and thus the point h in the former is represented by the point h' in the latter.

Again, draw perpendiculars from the two points in the plan which are represented by the letter D, and draw horizontal lines from the point in the elevation where the section-line cuts the line d—viz., d'—which, intersecting the perpendiculars, will give

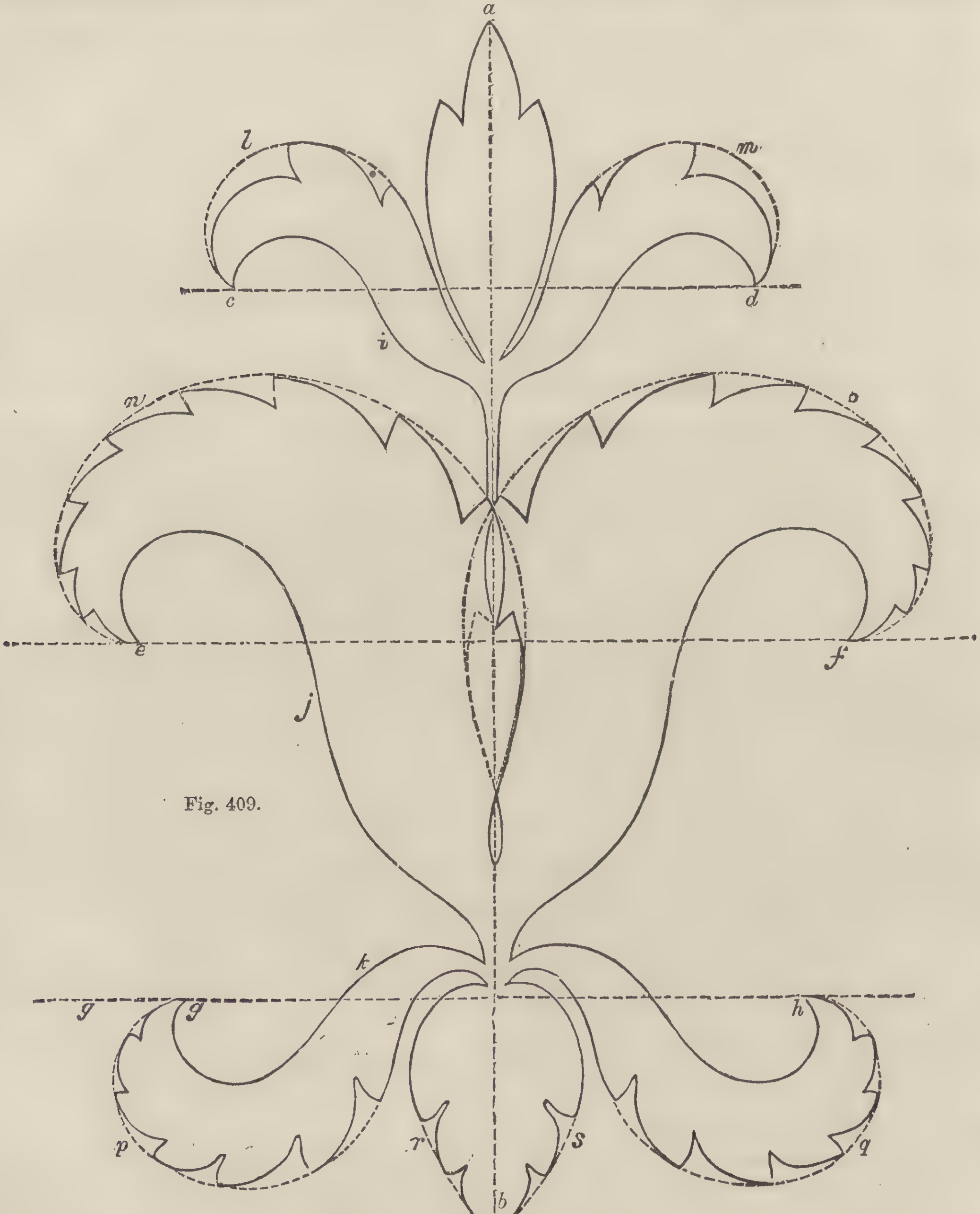


Fig. 409.

We now proceed to project a section of this cylinder taken on the given line $c' h$; that is to say, assuming that the cylinder is placed on an inclined plane, what would be the exact shape of a section taken vertically, the cutting plane entering at c' and proceeding directly downwards to h.

Now it has already been said that the points in the elevation c, d, e, f, and g, each represent two points; c' is then the projection of the diameter which is at right angles to the vertical plane, and which in Fig. 407 is seen at $c'' c'''$. The point d in the elevation (Fig. 406) is represented by the line $d'' d'''$ in the

the points $d'' d'''$; in the same manner $e'' e'''$, and any number of points, may be obtained: the curve $c'' e'' d'' h' d''' e''' c''$, joined by $c''' c''$, will then be the true section required.

Fig. 408 shows the true section on the line $a b'$—viz., that caused by a plane passing from the one extremity b' of the diameter of the top to the opposite extremity of the diameter a of the bottom, the cylinder being so placed that this section is a vertical one. This is to be projected in precisely the same manner as the last, and will not therefore require any further comment.

FREE-HAND DRAWING (*continued*).

Having already given a series of lessons in linear drawing by aid of instruments, we now revert to the practice of free-hand drawing, in order that the various branches of art may be cultivated in due course.

In commencing to copy the example (Fig. 409) which forms the subject of the next study, draw the central perpendicular *a b*, and the three lines *c d*, *e f*, and *g h* at right angles to it.

Next draw the curve *c i*, and the corresponding curve on the right side.

Then draw the curve *e j*, and that commencing at *f* to little space may be found for the required number of indentations. When the entire sketch has been completed, it is to be partially erased and "lined in."

The next subject for our study is a niche, standing in a pedestal, and surmounted by a pediment.

A *niche* in architecture is a cavity or hollow place in the thickness of a wall, in which may be placed a figure, a bust, a fountain, etc.

In commencing this example, draw the general outline of the plan (Fig. 410), and project from it the pedestal (Fig. 411) and body of the whole structure, carrying up the central perpendicular A B. Now at any convenient distance draw C D

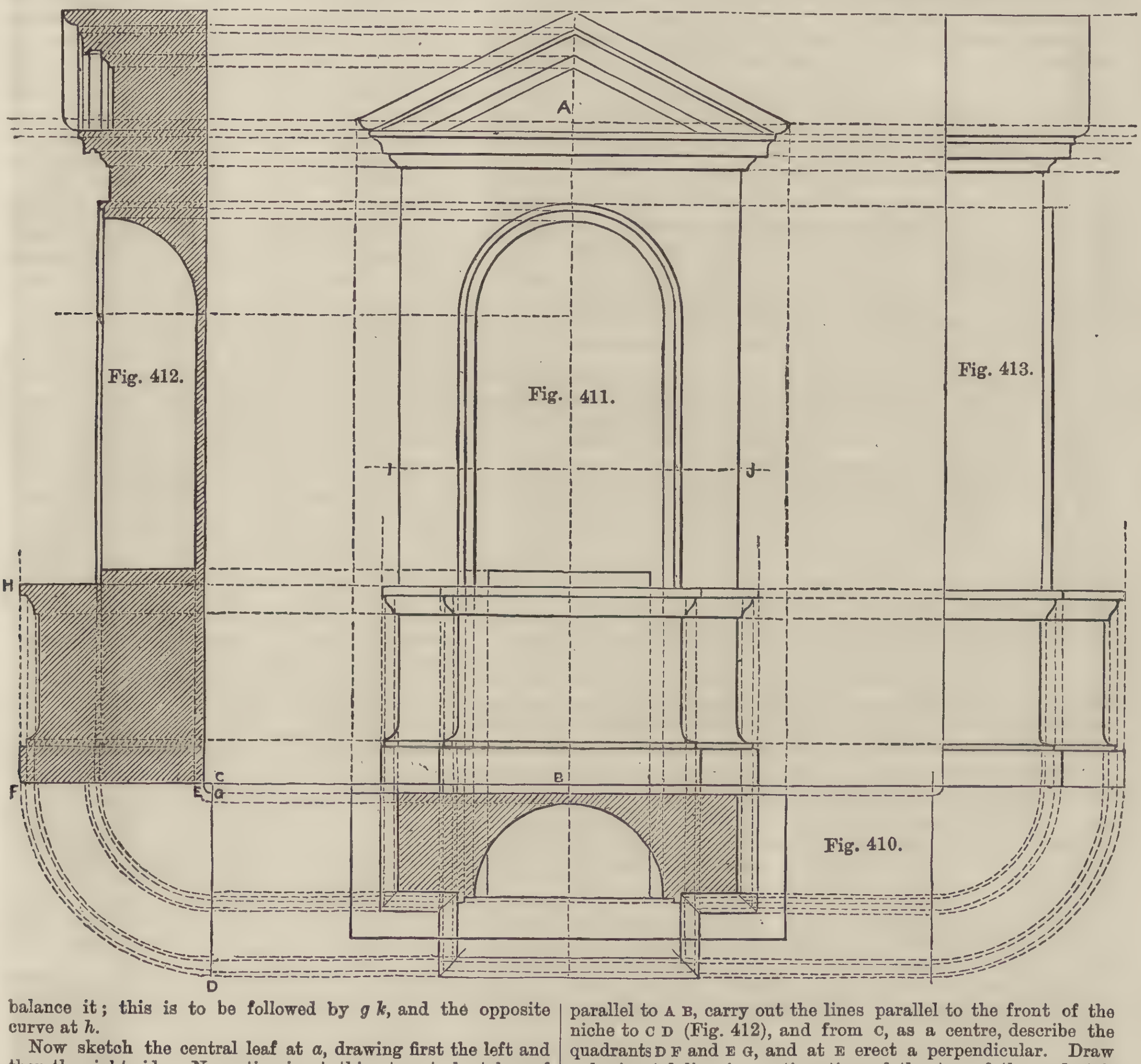


Fig. 412. Fig. 411. Fig. 413. Fig. 410.

balance it; this is to be followed by *g k*, and the opposite curve at *h*.

Now sketch the central leaf at *a*, drawing first the left and then the right side. No notice is at this stage to be taken of the indentations in the edges of the leaf, the whole of which is to be sketched in dotted or very fine lines, as shown at *l*, *m* and *n*, *o* in the example.

In the same manner sketch the general outline of the leaves *l*, *m*, *n*, *o*, *p*, *q*, and *r s*. It will be seen that the leaf *n* overlaps *o* in the middle; the underneath portion of *o*, which is covered by *n*, should, however, be carefully sketched, as by continuing it the upper portion of the leaf *o* is drawn.

The whole design having thus been outlined and corrected, the indentations of the leaves are to be drawn. The exact places for the points should be marked before commencing to draw them, otherwise it is likely that either too much or too parallel to A B, carry out the lines parallel to the front of the niche to C D (Fig. 412), and from C, as a centre, describe the quadrants D F and E G, and at E erect a perpendicular. Draw a horizontal line in continuation of the top of the pedestal, meeting a perpendicular drawn from F in H. This will give the extreme depth of the pedestal.

Now between F and H construct the exact sections of the mouldings of the pedestal, and having drawn from these perpendiculars as far as the line E F, draw quadrants from these points, using C as the centre; these quadrants meeting G D will give the points from which horizontal lines are to be drawn, which will be the plans of the mouldings, parallel to the back of the object; these meeting lines, drawn at the angles at 45°, will give the points at which the mouldings at right angles to the front are to be drawn.

From the points of intersection at these "mitres" perpen-

diculars are to be drawn, meeting horizontals drawn from the corresponding points between F and H, and thus the mouldings of the pedestal in Fig. 411 will be projected.

The horizontal section on the line I J is now to be added in the plan, and the elevation of the niche projected from it.

It is now advisable to draw the true section of the pediment, in order that the elevation may be projected from it. The forms of the various members, and also the upper part of the niche, will be understood from the example, and when these have been completed, their heights are to be projected on to the central perpendicular A B, and through the points the horizontal and raking mouldings of the pediment are to be drawn. The upper surface of the pediment may then be carried down to the plan, as shown by the dotted lines.

The same method is to be followed in projecting the side elevation (Fig. 413) from the plan and front elevation.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XIX.—SIR JOSEPH BANKS, F.R.S.

BY JAMES GRANT.

THIS eminent English naturalist, who did more for furthering the progress of natural history in the British Isles than any other man who graced the annals of science, was born in Argyle Street, Westminster, January 4, 1743. He was educated at Oxford, where he received a sound classical education, and where he remained until the death of his father, by placing fortune in his hands, enabled him to devote it and all his time to the development of knowledge.

In his twenty-second year he made a voyage to England's oldest colony, the bleak island of Newfoundland, and thence to the Labrador territory, on the east side of Hudson's Bay, a journey which ultimately led to his circumnavigation of the world. Captain (then Lieutenant) Cook having won favour as a bold and enterprising discoverer, it was resolved by Government to send him to the South Seas, that the investigations made in that quarter of the globe by Captain Wallis might be further pursued and perfected. Astronomy was to be considered, with all its interests, in this voyage, and orders were particularly given "to observe in the latitude of Otaheite an expected transit of the planet Venus over the sun." Inspired alike by a love of distinction and by scientific ardour, young Mr. Banks resolved to accompany Lieutenant Cook, and the Lords of the Admiralty lent all their aid to render the voyage both pleasant and successful; so he was accompanied by Dr. Solander, of the British Museum (a pupil of Linnæus), a secretary, two draughtsmen, and four servants; and sailed on the 26th of August, 1768, in the *Endeavour*, from Plymouth Sound.

His first adventures were in Tierra del Fuego, where he and the naturalists, his companions, nearly all perished in a snowstorm, during an expedition inland, made only for the purpose of exploration, and examining the natural products of that wild and barren country. As it was, Dr. Solander was so overcome by cold and torpor that but for the exertions of Banks his life would have been lost; and three of their attendants expired in the snow.

On the 12th of April, 1769, the *Endeavour* came to anchor off Otaheite, which had been discovered two years before by Captain Wallis, who named it George III. Island, and those on board were received with great kindness by the natives, who were gentle, good-natured, and hospitable. There the voyagers remained for three months, and Lieutenant Cook sailed round the isle in an open boat, and found it to consist of two peninsulas, with lesser isles adjacent, while his crew refreshed themselves after the recent hardships of their voyage, cultivating the good-will of the natives, and laying in stores of fresh provisions, and were refitting the ship to proceed farther. "At Otaheite, Mr. Banks, by the prudence, benignity, vigilance, and spirited activity which he eminently exercised in his intercourse with its inhabitants, contributed," we are told, "in the most essential manner, to prevent dissensions and disorders, and to promote that mutual harmony between those simple people and the English which was indispensably requisite to prevent the chief purposes of the voyage from being frustrated. His conduct was not that of a raw adventurous young man, or of a naturalist unfit for aught but collecting specimens, but of a man who knew himself and human nature, and possessed in a high degree the talents of beneficially guiding the designs and controlling the passions of others. Thus the specimens of natural history which he and his companions collected in these isles were very numerous and interesting."

Sailing from thence on the 6th of October, after a voyage of twenty-two days, they sighted the coast of New Zealand, which, though discovered by Tasman in 1642, was supposed to be part of a southern continent, till Cook found it to be two large islands separated by a strait. On this occasion, a priest of Otaheite named Tugio, who had voluntarily and confidingly accompanied them, acted as interpreter, and proved of vast service in their intercourse with the natives. Mr. Banks obtained here fresh specimens of plants and animals hitherto unknown to the learned world; and New Holland was the next scene of their explorations, when Captain Cook ascertained for the first time its separation by water from New Guinea. Botany Bay, as its name would indicate, afforded fresh treasures for the naturalist; and sailing thence along the eastern coast, it was taken possession of by Captain Cook in his Majesty's name, as New South Wales, and now forms a part of the British dominions. There the *Endeavour* struck upon a hitherto unknown rock, and all on board narrowly escaped death by drowning. Refitting the ship at the mouth of a strait, which they named after her, and which lies in the South Pacific, they proceeded on their voyage, and many strange shells and herbs were found; but the chief feature of the expedition was the discovery of the kangaroo, which was then deemed the most wonderful addition to the quadrupeds already known in natural history. Then a fever seized all on board; and nearly proved fatal to many; but after sailing for England, they came to anchor in the Downs on the 12th of June, 1771. A taste for discovery and scientific investigation had now become so strong in the minds of Banks and Solander that they sailed for Iceland, a country then but little known to the rest of Europe. On the way, accompanied by Dr. Uno von Troil (afterwards Bishop of Upsala), they visited many isles of the Scottish Hebrides, and particularly Staffa, the basaltic columns of which render it one of the greatest natural curiosities in the world. The discovery, if we may so call it, of Staffa must seem singular in these days of cheap trips and swift locomotion. Sir Joseph Banks and his companions chanced to visit the house of a Mr. Maclean, in the island of Mull, where they met a Mr. Leach, an Irish gentleman, who told them that the day before, in the course of a fishing excursion, he had fallen in with what was, in his opinion, one of the greatest wonders in the world, though none of his Highland friends seemed to feel any interest in it. His statement so greatly excited the curiosity of Sir Joseph and his companions, that they resolved forthwith to visit the island, and found it to be by far the most stupendous and striking example of basaltic architecture of which they had ever heard. At that time the Giant's Causeway in Ireland was the chief collection of pillars of basalt which was generally known to scientific inquirers; but since then many examples have been found in other countries. Singular to say, the existence of Staffa was almost unknown in England prior to this visit in 1772 by Sir Joseph Banks, whose description of Fingal's Cave attracted particular attention at the time. The hot-springs, the siliceous rocks, the animals and arctic plants of Iceland next occupied his attention, and were illustrated by drawings and descriptions.

On the resignation of Sir John Pringle in 1777, he was elected President of the Royal Society, a body of which he had become a most active member; and the result was that their attention was more particularly directed to the science of natural history. This election gave great offence to all the mathematical members, more particularly to Dr. Horsley, then Bishop of St. Davids; hence a schism was threatened, and even the formation of another society. But the goodness of temper and extreme suavity of manner displayed by Sir Joseph Banks at length calmed the storm, and soothed the temporary bitterness of Horsley and others; and his house in Soho Square became esteemed as the very seat of science, and one of the great intellectual centres of the metropolis, where learned and distinguished men from all countries were entertained with equal hospitality and kindness. Every Sunday evening during winter a meeting took place there, when new discoveries of every kind were communicated and discussed, papers were read, specimens exhibited, or models

prepared; while his great collection of books illustrative of natural history were open to the inspection of all. As Sir Joseph Banks was not without literary enemies, there were some to take exception to the day selected for these periodical meetings, more especially as his visitors "were all men in that rank of life which forbade even the remotest probability of their being actively engaged in more worldly pursuits during the remainder of the week."

He was the sincere friend and patron of Ledyard and the other African explorers, and our West Indian colonies were greatly indebted to him, for by his instrumentality and advice the famous bread-fruit tree of Otaheite was introduced into several of the islands; and as its superiority over the native plaintain is well known, it has long since surpassed that valuable tropical production, both in nourishment and utility. It was by his influence that the home Government was induced to explore the shores of New Holland, suggesting measures to conciliate the savage natives, and thus save travellers or settlers from the dangers to which they had previously been exposed. In London his quiet and unostentatious readiness to relieve the pecuniary wants of all literary and scientific persons was long remembered with gratitude by many to whom his liberality was extended.

In his latter years he devoted a great portion of his time to agriculture, and carried on an extensive correspondence with many statistical writers in connection with that branch of knowledge, and particularly with Sir John Sinclair, of Ulbster, whose "Code of Agriculture," published in 1819, went rapidly through several editions, and was translated into the French, German, and Danish languages. Sir Joseph Banks, writing to Sir John in October that year, says: "I rejoice to hear that your 'Scottish Agriculture' has met with so extensive a sale. The adoption of it in England will probably be the consequence, and a more beneficial one can scarcely be conceived. That a Scots farmer can get *more* from the earth than an English one seems a fact not to be disputed. To have been the cause of imparting to Englishmen the skill of Scots farmers is indeed a proud recollection." But Sinclair's "Code" failed to achieve any change in England.

Sir Joseph Banks died of gout, on the 19th of June, 1820, bequeathing all his collections, library, herbarium, manuscripts, and drawings ultimately to the British Museum.

PRINCIPLES OF DESIGN.—XXI.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

HANGINGS, Etc. (*continued*).

As we were speaking of damask table-linen in our last chapter, it is perhaps well that we notice one peculiarity of a table-cover, which is this, that while the central portion is seen flat, the border portion is viewed in folds; and here we come to one of the great peculiarities of draperies generally, that of their being viewed not as flat surfaces, but in waved surfaces. One portion of a table-cloth is, however, seen when flat, but this is almost an exception in the case of draperies. Another exception to this rule of hangings appearing in folds, and that of a very complete character, occurs in silk damasks which are used as a rich lining to the walls of palaces and some mansions; but of table-cloths we will speak for the present.

The central part of a table-cloth, that portion which is always to be viewed as a flat surface, may be enriched with any diaper pattern that is simply treated, and this diaper pattern may be full of design, provided the parts are not too large or too small. It may also be formed of gracefully-curved parts, or of straight lines or circles, or of any combination of these elements; but, preferably, not wholly of straight lines.

Were it not for the fact that much of this central portion of the cloth is to be covered by articles of the dinner-table, it might well be formed as a central ornament, repeating only in quarters; but as such an ornament, in order that it be satisfying, requires to be seen as a whole, it is not desirable that such be here employed. A diaper pattern that repeats many times in the centre is preferable, as the pattern can be seen in a satisfactory manner.

The border of a table-cloth, like all fabrics that are to be seen in folds, requires special treatment, for what looks well when seen as a flat surface may not look well when seen on a waved surface. Tender and graceful curves are lost when viewed upon folds, for they here appear as mere wormy lines. On the contrary, right lines, whether horizontal or diagonal, and circles, all look well when seen upon waved grounds. These lines become, owing to the folds of the fabric, curves of a subtle character. The manner in which lines become influenced by falling on a curved surface can be readily illustrated by forming semicircles of paper, and folding them into cones, after having drawn upon them a series of circles (Fig. 71) or straight lines (Fig. 72). If these cones (Figs. 73, 74) are now viewed from above, or in such a manner that the eye rests over the apex, it will be seen that the circles have now become richly-varied curves, each having somewhat the form of a blunt heart or cardioid (Fig. 75), and that the straight lines become horse-shoe shaped (Fig. 76). These illustrations will be sufficient to show that what is plain when seen upon a flat surface may be delicate and satisfying if seen upon a curved surface; and will also lead us to understand that what may be delicate and refined when seen upon a flat surface may become feeble and unsatisfactory if falling upon a waved ground. I have said that stripes or straight lines, if *crossing* a folded fabric, are satisfactory. This is so in almost all cases, the only exception being in ladies' dresses. Here lines crossing the fabric are not satisfactory, as they become rings around the body, which appear to divide it into hoop-like strata. The patterns of dresses *may* consist of narrow, vertical stripes, as these are collected together at the waist of the figure, and fall into graceful curves with any motion of the body, but the very opposite is the case with window-hangings. All vertical stripes are here highly offensive, while horizontal stripes are thoroughly satisfactory.

A consideration of the window-hanging materials made in Spain, Algeria, and on the Morocco coast, will show us the beauty of horizontal stripes; and in some of the little Algerian warehouses, such as we have in Regent Street, London, and in the Rue de Rivoli in Paris, we see some of these fabrics of a most interesting character.

To state in a concise form the laws which should govern the application of ornament to curtain fabrics which are to be seen in folds, I should say—

1st. Great simplicity of pattern is necessary.

2nd. Circles, straight lines crossing the fabric, and diagonal lines are all correct in such a case, and are improved by the folds, which form them into subtle and beautiful curves (Fig. 77).

3rd. If curves are tender and graceful, they become commonplace on a waved or folded ground.

4th. The size of the pattern should be considered in relation to the size of the folds of the material.

In Germany a kind of ornament is applied to rich stiff fabrics which is almost peculiar to the country. This ornament is rich, bold, hard, or stiff in its lines, and in every way adapted for the decoration of a costly fabric which falls in large folds, the folds changing the hard and stiff lines into graceful curves. This should also be noted respecting these curious yet beautiful patterns, that they are always simple in plan, however rich in detail, and are invariably founded on a geometrical basis. "German Gothic" is a name by which such ornament may be distinguished (flat Gothic ornament has always been quite distinct from the stone and metal ornaments of Gothic buildings, which have solid, and not merely superficial form). In our last article we engraved one illustration of this form of ornament, and with this article we engrave another of the same character. (Fig. 78). This particular class of ornament forms the background to many old pictures, a most interesting collection of which exists in the museum of Cologne, and is certainly worthy of the most careful study.

As to flat silk wall-damasks, which are used in some of the upper-class houses as wall-papers are used in the lower-class houses, all that need be said respecting them is that they should be treated as wall decorations, and not as fabrics which are to be seen folded. Were I asked whether I approve of these damasks as wall coverings, I should say, "Certainly not." A wall is better treated as a wall, and not so covered with drapery as to leave space for vermin between the wall and its enrichment. There is also the further objection that the lines where the fabric is joined are visible, and these are most certainly objectionable.

Besides the illustration of German ornament which we gave in our last article, we figured also a specimen of Indian embroidery on cotton. I cannot too strongly recommend the

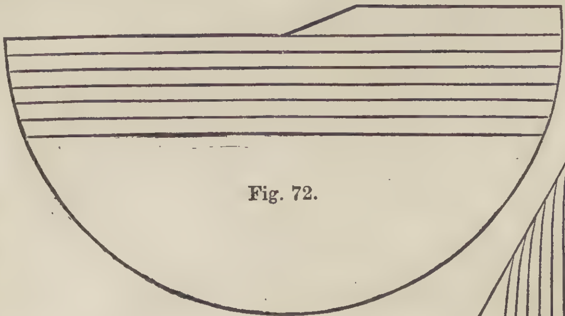


Fig. 72.

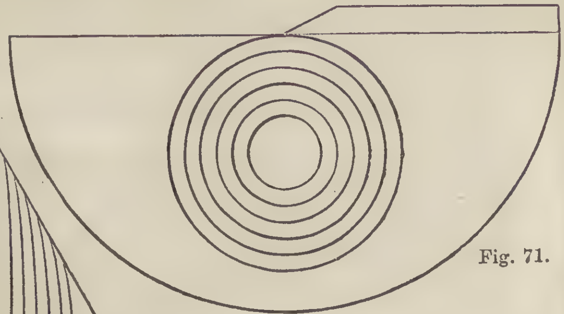


Fig. 71.

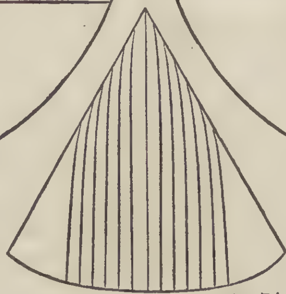


Fig. 74.

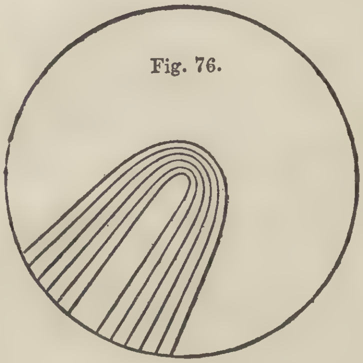


Fig. 76.

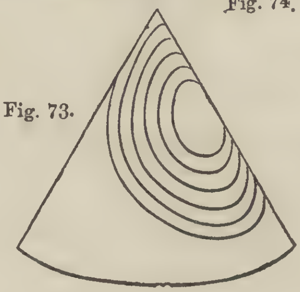


Fig. 73.

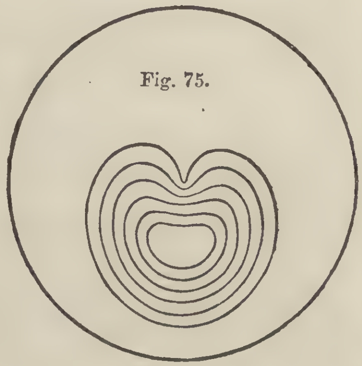


Fig. 75.

Fig. 80.

Fig. 79.

designer of patterns for woven fabrics to study the native fabrics of India, exhibited at the Indian Museum, Whitehall.

Besides the collection here brought together, there is also in most of our manufacturing towns a large series of specimens of these cloths deposited with the Chamber of Commerce, and these can be consulted by all respectable members of the community. Speaking of these Indian fabrics, Mr. Redgrave says, in his Report on Design prepared for the Commissioners of the International Exhibition of 1851:—"These are almost wholly designed on the principles here presumed to be just ones—the ornament is always flat, and without shadow; natural flowers are never used imitatively or perspectively, but are conventionalised by being displayed flat and according to a symmetrical arrangement; and all other objects, even animals and birds, when used as ornament, are reduced to their simplest flat form. When colour is added, it is usually rendered by the simplest local hue, often bordered with a darker shade of the colour, to give it a clearer expression; but the shades of the flowers are rarely introduced. The cloth of gold figured in the loom (Fig. 79), and part of an Indian scarf (Fig. 80), illustrate fully these remarks. The ornament is geometrically and symmetrically arranged, flat, in simple tints, and bordered, as above described, with darker shades of the local colour. The principle of colour adopted is a balance of the complementaries red and green, in both cases with white introduced to give points of expression; and to lead the eye to the symmetrical arrangement of the ornament. In Fig. 79, purple is introduced to harmonise with the gold ground, a harmony very frequently used in the rich tissues of India. In Fig. 80 variety has been obtained by introducing two reds, giving an interchange of a lighter tint in every other flower in the border. The borders of these scarves are beautifully illustrative of the simple and graceful flowing lines which characterise Indian ornament; and in Fig. 80 we can observe the difference between the Eastern and the mediæval patterns—while the same principles are acknowledged in both, the latter are often stiffer and more angular than the graceful sprigs of this border. Both these works show how much beauty may be obtained by simple means, when regulated by just principles, and how perfectly unnecessary are the multiplied tints by which modern designers think to give value to their works, but which increase the difficulties of production out of all proportion to any effect resulting from them—nay, often even to the absolute disadvantage of the fabric. If we look at the details of the Indian patterns, we shall be surprised at their extreme simplicity, and be led to wonder at their rich and satisfactory effect; it will soon be evident, however, that their beauty results entirely from adherence to the principles above described. The parts themselves are often poor, ill-drawn, and commonplace; yet, from the knowledge of the designer, due attention to the just ornamentation of the fabric, and the refined delicacy evident in the selection of *quantity* and the choice of tints, both for the ground, where gold is not used as a ground, and for the ornamental forms, the fabrics, individually and as a whole, are a lesson to our designers and manufacturers, given by those from whom we least expected it."

Fig. 77.

Fig. 78.

Much that Mr. Redgrave here says is worthy of careful consideration, and I can do no more than recommend the student to study these beautiful Indian fabrics, and consider them in conjunction with the remarks which we have made respecting them and fabrics in general.

FARMING AND FARMING ECONOMY.—V.

By Professor Wrightson, Royal Agricultural College, Cirencester.

TREATMENT OF FALLOWS, Etc.

The bare or naked fallow has ceased to exist over large tracts where it once obtained; and yet we cannot treat this method of cleaning and fertilising land as obsolete. Drainage, steam cultivation, the use of portable manures, and improved appliances are causing its gradual disappearance, but the final result is still distant, and the process of bare-fallowing still demands a place in an agricultural treatise.

In discussing fallows, we must divide our subject into two parts:—(1) The working of bare fallows, and (2) the treatment of root or green-crop fallows.

BARE-FALLOWING.

Upon light and medium soils, a bare fallow is rarely and ought never to be seen; while upon stiff land it may occasionally be adopted with advantage. The objects of fallowing, whether bare or otherwise, are twofold—(1) to clean, and (2) to enrich the soil. We have already shown (No. IV.) how these objects are accomplished, either by a system of root-crop cultivation or by tilling the land without a crop. There are, however, very important differences in the working of these two descriptions of fallows. Our root-crops—and we especially here refer to swedes and turnips—require a moist, finely-tilled seed-bed; or, in other words, they need the most favourable conditions for germination and growth. Such a fine, and at the same time moist, state of soil is best obtained by autumn ploughing and by as little spring cultivation as is consistent with the destruction of weeds. Hence autumn cultivation is the surest method of obtaining good root-crops. In bare-fallowing land, an opposite condition of soil is desired. Here, no intermediate crop is contemplated, but the farmer looks forward to the direct success of his wheat. It is his intention to till the land throughout summer, to thoroughly expose it to atmospheric agencies, to employ the solar heat to scorch up every weed, and to present his land to the same influence, that it may be baked through, afterwards to fall "like lime" under the influence of heavy rain. Finally, by the middle of August, it is his object to secure a seed-bed for his wheat, composed of a mixture of fine earth and clods, which the coming frosts of winter may crumble down about the young wheat, and thus prevent the roots from being "thrown out." With these objects in view there is but small inducement to undertake the cultivation of a bare-fallow in the autumn. There are indeed good reasons for not doing so. Autumn cultivation would result in too fine a condition of soil for the above purposes, and not only so, but time being limited in the fall, it will be well to devote the energies of the farm to the cultivation of land intended for mangel-wurzel, potatoes, and swedes. The working of bare-fallows will, therefore, be commenced in the winter, by breaking up the stubbles with a strong plough, drawn by three or four horses, according to the tenacity of the soil and the depth of the furrow. With reference to this last point, depth, it is difficult to speak positively. Deep ploughing is, as a rule, to be recommended; but there are exceptions, as where the cultivated surface is underlaid by hard, sour, yellow or blue clay, which has never yet been brought under the ameliorating influences of air, light, and vegetation. Here indiscriminate deep tillage would act prejudicially, by mixing a large quantity of raw, unworked clay with the surface soil. In such cases we should recommend a gradual deepening of the soil during a series of years, in preference to at once increasing the depth, and we should prefer the extra deep-ploughing to be performed during the autumn months, so as to allow of the action of frost upon the newly brought-up earth.

Returning to the treatment of ordinary fallows, the land may be ploughed seven to eight inches deep in winter; the usual practice being to split or cleave the ridges. The second ploughing takes place in the spring, when the furrow is turned back or reversed. It is cross-ploughed in the summer, and by this means the land is thrown up very rough under a burning sun, which destroys every blade of vegetation. Drag-harrowing, grubbing, and weed-picking follow, by which the clods are partially broken and turned over, so as to present new surfaces to the sun and air. A fourth ploughing in the same direction as the first is the next operation, after which dung is carted and spread on the surface, and the operations are concluded with a fifth furrow, known as the seed-furrow.

As there are many modifications of bare-fallowing, we add to the above general description the treatment recommended by Mr. Stephens, in his recent edition of "The Book of the Farm." Fallow land, we are told, is the last stubble-ploughing in winter, and is done in the same manner as for potatoes and turnips. Then comes cross-ploughing in the spring, after which the land is left, and the energies of the farm are concentrated upon turnip cultivation. When leisure permits, attention is once more bestowed upon the fallow, and it is at this stage that Mr. Stephens gives minute directions, too detailed for our present purpose, for freeing the land from weeds. Subsequently he tells us "it is impossible to determine beforehand how many times bare-fallow should be ploughed, harrowed, grubbed, and clod-crushed, to make it clean, but it should be borne in mind that such is the object of bare-fallowing."

Dung is applied at the end of July, at the rate of 12 to 15 tons per acre, and ploughed in, in drills running diagonally across the future ridges. By this mode of manuring the dung putrefies readily, and after the drills are harrowed down, and the seed-furrow is given, the dung becomes intimately incorporated with the soil. Bayldon thus gives in detail the cost attendant upon this laborious operation:—

	£	s.	d.
First ploughing in winter, with three horses, a man and a boy, at the rate of three roods a day	0	12	0
Grubbing fences and clearing ditches	0	0	6
Second ploughing in the spring	0	10	0
Three strokes of harrows, 2s. 3d.; rolling, 1s.; gathering couch grass, 2s.	0	5	3
Third ploughing across, 10s.; harrowing, 1s. 6d.; scarifying, 4s.; harrowing, 1s. 6d.; gathering couch, 2s.; rolling, 1s.	1	0	0
Fourth ploughing with manure	0	8	0
Seed-furrow, 8s.; three strokes of harrow, 2s. 3d.; water furrowing, 2s. 6d.	0	12	9
Total	£3	8	6

In parts of Essex nine ploughings are sometimes given to make a fallow, while in North Kent one ploughing is thought sufficient, or two at the utmost. The above descriptions of the process are usually followed.

ROOT-CROP AND GREEN FALLOWS.

It is impossible to estimate the importance of the "root-crop" to the nation. It is owing to the extension of this cultivation that fresh meat has become a possibility throughout the winter; that the amount of fat stock has been indefinitely increased; that an increasing population has to a considerable extent obtained employment, and that a strong impetus has been given to agriculture. Root and green crops now occupy land which would formerly have been under a system of naked-fallowing, and, as has already been insisted on, they do so in harmony with the objects of fallowing. When consumed on the farm, they return all and more than they receive to the soil, and thus increase its fertility, while the interculture to which they are subjected secures the cleansing of the land. The root-crops ordinarily cultivated may be divided into the following groups: swedes, yellow turnips, white turnips, mangel-wurzel, and carrots, to which may be added, by stretching a point, kohl-rabi, cabbages, rape, and potatoes.

These groups represent a considerable number of species, each of which has numerous varieties and sub-varieties. We cannot pretend, in the limited space allotted us, to even give a list of all these plants, but must confine ourselves to little more than a general description of each type.

The swede constitutes the main root-crop of this country. It is at once distinguished by its smooth bluish-green leaves, its cylindrical form, and its compact flesh. Its skin is either of a dull purple or dull green colour; by which property the group is divided into purple-topped and green-topped swedes.

The first group is well illustrated by Skirving's purple top, Laing's purple top, or strap leaf, the East Lothian purple top, etc.; and the second group comprises the green top and the white swede. By far the larger number of varieties before the public belong to the purple-skinned sorts. Swedes require land of good or moderate fertility, and form, owing to their keeping properties and hardihood in time of frost, the staple food of sheep and cattle from January to the end of April.

Turnips are at once recognised by their rough vine-green leaves, their usually ob-ovate form, and the softness of their flesh. They are classified by the colour of the skin and of the flesh, and by their form; thus we find green top, purple top, red top, white, mottled, yellow, fleshed, and white fleshed. The changes capable of being rung upon these characters are almost endless, and we accordingly find green-top yellows, purple-top yellows, green-top white, purple-top white, common white globe, Pomeranian white globe, grey stone, etc. Some of these turnips claim to be of hybrid origin, which again introduces us to a new series of green and purple topped hybrids; others are of a long tankard form, still further complicating the nomenclature. Some are hardy, while others are easily damaged by frosts. They grow quicker than swedes, and usually are consumed before hard frosts set in; although late-sown turnips will stand an ordinary winter.

Turnips will thrive upon poor light soils, where swedes could not grow successfully.

Mangel-wurzel is of less general cultivation, but is seen covering a large area in the south of England. It cannot resist frost, and is well adapted for withstanding drought, both of which conditions indicate its fitness for a warm climate. On the other hand, the north of England and Scotland are eminently adapted for swede and turnip cultivation, these plants preferring a cold and moist climate. Mangel-wurzel is very free from insect attacks, as well as from mildew and blights, and may be depended upon for a full crop. It is suitable for stiffer soils than either turnips or swedes, and possesses wonderful keeping properties. The principal varieties are named according to form and colour—namely, the orange globe and long yellow, and the red globe and long red.

Carrots are often grown as a field crop, the white Belgian variety being in most favour. This crop requires deep loamy soil, free from stones.

Kohl-rabi cannot properly be spoken of as a root-crop. Its fleshy or cellular portion, used as a cattle food, consists of an expansion of the stalk upon which leaves grow, leaving a scar when they fall. Kohl-rabi is much esteemed upon the fens of the east of England, where turnips are apt to grow hollow in the middle, and mangold does not succeed. It is also well adapted for the stiffest classes of soil, upon which it may be sown, or planted out from seed-beds like cabbages.

There are several varieties of kohl-rabi, among which we may mention the purple oblong and round, and the green oblong and round, as well as the curly or Neapolitan and the artichoke-leaved variety.

Cabbages, both late and early, close and open headed, usually form an excellent crop for stiff soils. A considerable amount of attention is being given at the present time to their cultivation.

Rape is closely allied to swedes, and is cultivated in this country exclusively for its leaves, which form an excellent food for sheep.

Potatoes comprise an almost endless variety, but as they are scarcely to be ranked with the foregoing as stock foods, we shall leave them for a future chapter.

It is worthy of notice that by a proper selection of the above-noticed plants land of almost every shade of quality can be suitably cropped, and live stock may be provided with food throughout a winter lasting from the first of October to the last of April. Light lands will grow turnips; medium soils, swedes; stiffer soils, mangel-wurzel; and the heaviest clays, kohl-rabi and cabbages. Again, turnips will give an abundant supply of food up to Christmas; swedes will be good until the end of April; and mangel-wurzel will keep, under favourable conditions, for two years. We will now pass on to briefly consider the cultivation for "roots."

PREPARATION OF LAND.

In working land for roots, a very different system of cultivation is pursued to that previously prescribed for bare-fallows. Taking the case of clean land of medium tenacity, we should recommend the following course of tillage to be sufficient. One deep autumn ploughing, after which the land lies until near the time for root-sowing. Weeds are then got rid of by the "cultivator," and the land is harrowed, and sown on the flat or on the ridge as the case may be. Such a cultivation can only be carried out upon clean land. Where land is foul, a more complicated system must be used. As soon as harvest is over, the stubbles are pared with a paring-plough or broad share of some kind. Thus the top is disturbed for about 1½ or 2 inches in depth; harrows and rollers follow, and by their action, supposing the weather to be favourable (dry), separate the earth from the roots of weeds. This practice is founded upon the fact that immediately after harvest *couch* lies near the surface, and can be readily separated from the under soil by a shallow cultivation. The weeds being separated from the adhering soil, they are raked together and burnt; the ashes are spread and dung is carted on to the land at the rate of from 15 to 25 single horse-loads (weighing about 15 cwt. each) per acre. A deep ploughing is the next operation, after which the land rests through the winter, receiving the pulverising influences of changes of temperature. There are many advantages in thus anticipating the cleansing process by autumn cultivation. The land is not dried by repeated ploughings during spring; a fine surface is ensured by the action of changes in temperature; eggs of insects and seeds of weeds are destroyed, and work is accelerated.

The precise amount of cultivation which land may require in the spring is ever varying. All we can say is, the less the better for the success of the root-crop; although, at the same time, there are cases in which the foulness of the land necessitates a considerable amount of spring work. We believe it is sound policy to insist on the land being clean, even if the crop is thereby sacrificed, because otherwise the object of fallowing is frustrated.

OBJECT DRAWING.—IX.

THE subject of the present study (Fig. 52) is the cross when placed vertically, its front elevation being at right angles to the plane of the picture.

As already explained, this cross would be contained in a square slab; but it must be clearly understood that the principle of thus generalising the form would be applicable whatever might be the proportions of the arms.

Having, then, sketched the slab, draw at the middle of the side which is parallel to the plane of the picture, the square representing the end of the horizontal arm, and draw lines from the angles of this square to the point of sight; the length and thickness of this end of the arm will be regulated by the distant side of the slab, which is, of course, parallel to the near side.

Now draw a diagonal, *a b*, which, cutting the lines of the horizontal arm, will give the points *c* and *d*, through which the lines forming the face of the upright arm are to be drawn; the rest of the figure will be readily understood from the drawing.

Fig. 53.—It having thus been shown that the cross which formed the subject of Fig. 52 is contained in a square slab, it will readily be seen that if the additional arms (Figs. 49 and 50) are inserted, the cross will have six equal arms, and thus, instead of inclosing it in a square slab, a cube would be required for the purpose.

We will proceed, therefore, to sketch a cube placed at an angle to the picture-plane—viz., *a b c d e f*.

Between *a* and *c*, and between *a* and *e*, mark *g* and *h*, and *i j*, representing the perspective widths of the arms which touch the sides of the cube.

From *g h* and *i j* draw lines, which in the object would be parallel to the sides of the plan, and therefore in the drawing must tend to the same vanishing-points—viz., *g k*, *h l*, *i m*, and *j n*.

These lines give the perspective view of the plan of two slabs, intersecting each other at right angles; and it will be evident that in these two planes the arms of the cross will be contained.

From these points erect perpendiculars, which, being joined on the upper surface of the cube, will complete the view of the two intersecting planes; the lozenge-shaped form caused by the crossing of the planes representing the square upright, which is common to all the arms.

It now remains to (as it were) hew the horizontal arms out of these two vertical slabs; and it will be seen that these arms are in themselves portions of a third slab, intersecting the

other two horizontally; therefore, in the middle of the line *a b*, mark *o*, *p* equal to the real thickness of the arms, and from *o*, *p* draw lines to each of the vanishing-points.

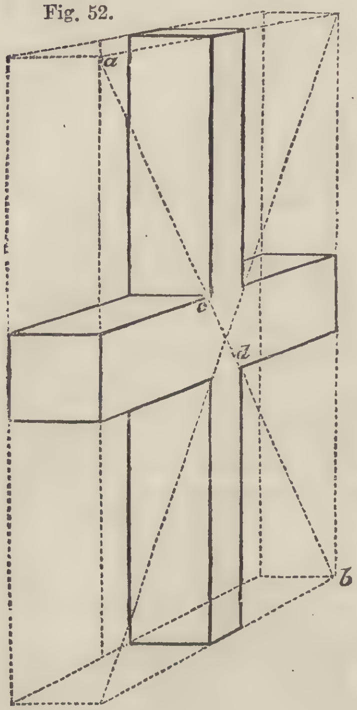
These lines will cut the perpendiculars *g*, *h* in *q*, *r*, *s*, *t*, and *i*, *j* in *u*, *v*, *w*, *x*, these lozenges representing the ends of the arms on the sides of the cube nearest the spectator.

From the points *q*, *r*, *s*, *t*, and *u*, *v*, *w*, *x*, therefore, lines are

From *a* and *b* set off *a c* and *b d*, representing the width of the blocks which are to take the position of legs. Draw lines to the point of sight.

These will cut the diagonals in four points, which will be the inner angles of the plans of the legs. The complete plan being thus prepared, it is to be left whilst the general form is proceeded with.

Fig. 52.



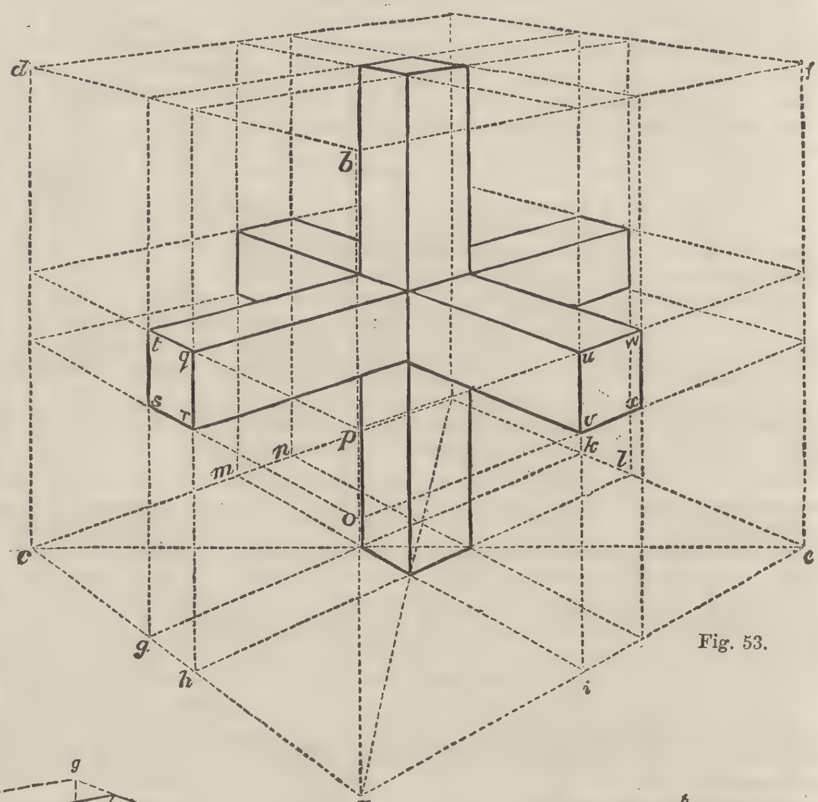


Fig. 53.

Fig. 56.

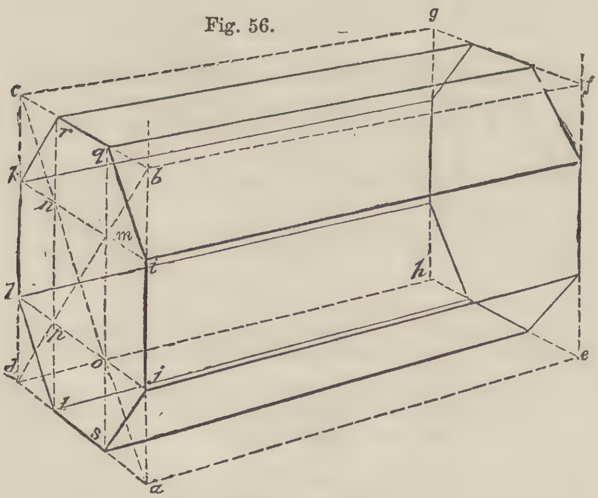


Fig. 57.

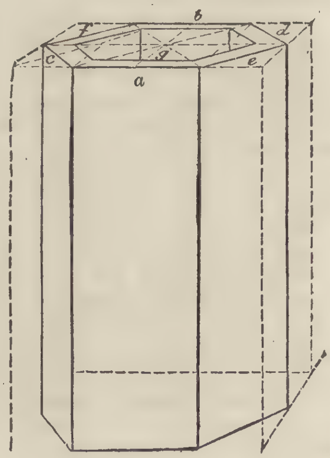
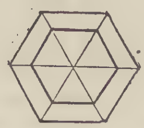


Fig. 58.



to be drawn to the vanishing-points, and thus the object will be completed, care being taken that the distant ends of the arms are absolute continuations of those nearest the spectator.

The object (Fig. 54) in the next study contains the leading principles involved in drawing a table or stand for a machine, etc. It consists of four oblong blocks, the cross section of which is a square, and of a square slab, the thickness of which is equal to that of the oblong blocks.

The oblong blocks are placed so as to form the corners of a square; therefore, in the first place, sketch the perspective view of such a square, and draw diagonals.

Draw perpendiculars, *a e* and *b f*, equal to the length *a b*; for, as in the models now before us, the length of the slab *e f* is fourteen and its thickness two inches; and as this slab rests on uprights twelve inches high, the front becomes a square, and the general form of the object is a cube. Now draw the line *f h*, representing the thickness of the slab, and from *h* draw a line to the point of sight. Perpendiculars raised from the points already marked in the plan will complete the general view of a square table.

Fig. 55 shows how a stool may be similarly drawn. This object is placed so that its sides are at angles to the picture.

The shading in these objects will require no explanation, and its general character having been glanced at in the drawing now before us, should be studied from the actual group of models.

Fig. 56.—The subject of this lesson is an octagonal prism lying on one of its long sides—its axis, and consequently the sides and ends, being at angles to the plane of the picture.

As in the former case, the proper method is to imagine the prism to be enclosed in an oblong block having square ends.

The method of obtaining the perspective view of an octagon has been shown in Fig. 46. It is not, therefore, necessary here to repeat that elementary figure, since, although in the present study the octagonal end is vertical, and at an angle, and in the former view it is horizontal, the near and distant side being parallel with the picture-plane, the result is obtained in a similar manner, the lines, however, being drawn to the vanishing-point instead of to the point of sight.

Having, then, sketched the oblong block *a b c d*, *e f g h*, and having marked upon *a b* the points *i*, *j*, draw lines from these to the vanishing-points of the lines *a d* and *b c*.

These lines will cut *c d* in *k* and *l*, then *i j* and *k l* will be two sides of the octagon. Now draw the diagonals *a c* and *b d*, cutting *i k* in *m* and *n*, and *j l* in *o*, *p*.

Draw vertical lines through *m o* and *n p*, meeting *b c* in *q*, *r*, and *a d* in *s*, *t*; then *q r*, *s t* will be two more sides of the octagon. Join *q i*, *r k*, *l t*, and *j s*, and the view of the octagonal end will be completed.

It is only now necessary to draw lines from each of the angles of this end to the vanishing-point of *b f* and *a e*. These lines will cut the sides of the quadrilateral *e f g h*, and give the points for the distant end of the prism. This object is purposely rendered as if transparent, and without shading, so that the working may be clearly seen. It is needless to repeat, that the lines here shown would not all be necessary to the advanced student; but it is the knowledge of the principles laid down, combined with practice, which gives facility in drawing either from the objects, from memory, or from imagination.

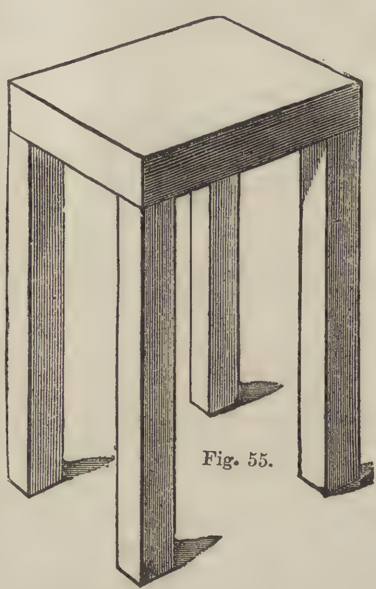


Fig. 55.

Fig. 57.—This is a sketch of a hexagonal prism, which is given to show the application of the same method to another polygon. In this case, however, the object is supposed to be hollow.

Now if the side *e* of the hexagon were continued until it reached the horizontal line, the intersection would be the vanishing-point for all lines parallel to *e* (the student will remember that "all lines which in the object are parallel to each other vanish to the same point"); therefore *e* and *f* should converge to the vanishing-point on the right side, whilst *c* and *d* should be drawn to the point on the left.

Now it will be clear that the lines forming the inner edge of the sides of this hollow prism would in the object be parallel to the outer lines, and that they would meet on the diagonals of the hexagon, as in Fig. 58.

Therefore, having drawn diagonals in the figure which is to represent the upper end of the hexagonal prism, draw the line *g* parallel to *a*, and at such a distance within it as may seem desirable. From the points where this line cuts the diagonals, draw a line to each vanishing-point, meeting the diagonal which is parallel to the plane of the picture. From these points lines are to be drawn to the opposite vanishing-

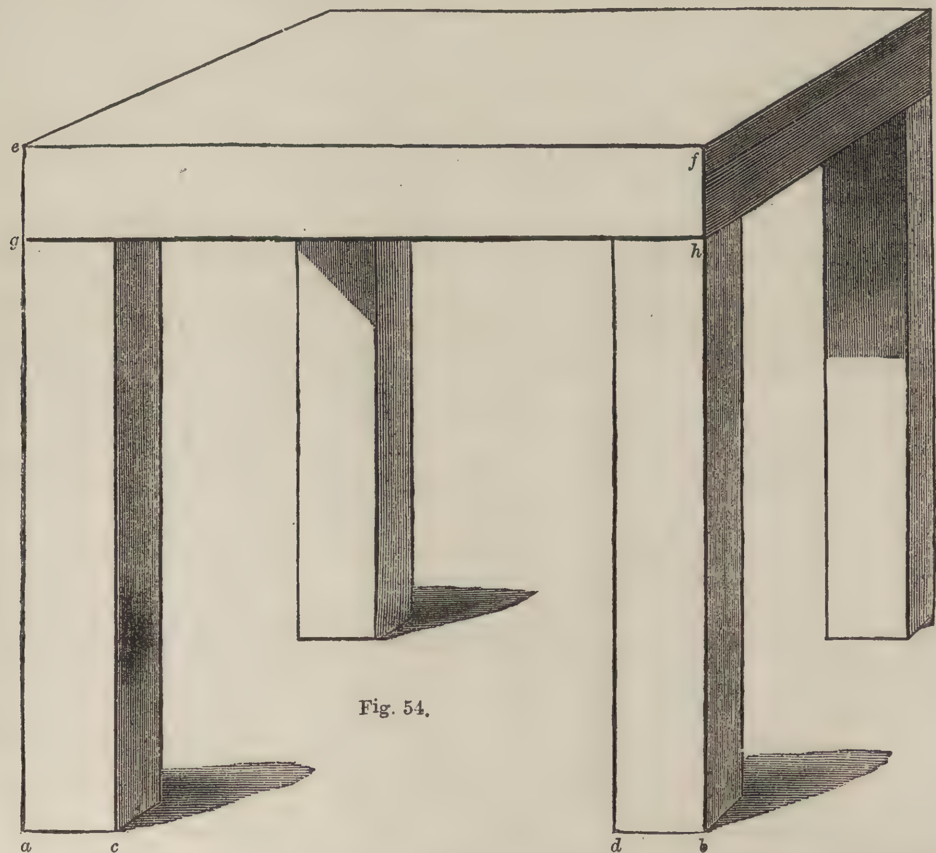


Fig. 54.

points, meeting the next diagonals; then a line uniting these intersections will complete the figure, and it will be evident that this line will be parallel to a, g, and b.

SEATS OF INDUSTRY.—XVIII.

LYONS.

BY WILLIAM WATT WEBSTER.

THE silk manufactures of France are far more extensive and far more various than those of England; and Lyons, the second city in France as regards population, is not only the most important of the manufacturing centres of France, but it is also the chief seat of the silk trade and manufactures of Europe. This ancient and prosperous city is situated partly on a tongue of land formed by the junction of the rivers Rhone and Saône—the former being at this point about 650 feet wide, and the latter about 480, and both being lined with wharves and crossed by handsome and commodious bridges—and partly on the opposite banks of the two rivers. Its position at the confluence of these two navigable rivers, affording ready communication with the Mediterranean, has made Lyons the depôt for the silk of Italy in transit to other countries. It lies also in the centre of that part of France where the cultivation of silk has been prosecuted with the greatest success, and on the largest scale.

According to certain antiquaries, Lyons, or, as its inhabitants call it, Lyon, was originally founded two centuries before the Christian era, by that colony of Phocæans who in 600 B.C. built Marseilles, and at an early period established a flourishing republic, celebrated for the wisdom of its institutions. But this view is not supported by sufficient evidence, and is discredited by the fact that Cæsar makes no mention of *Lugdunum*, which was the name given to the city by the Romans. From a statement in the writings of Dion Cassius it appears that Munatius Plancus settled fugitives from the adjoining towns in Lugdunum, about the year 40 B.C., and he is generally regarded as the original founder of Lyons. Augustus made it the capital of Celtic Gaul, which received the name of *Gallia Lugdunensis*. At that time Lugdunum possessed a senate, a college of magistrates, and an athenæum, and subsequently it acquired additional importance as the centre of the four great roads that traversed Gaul. In 58 A.D. it was burned to the ground in one night, but was rebuilt by Nero, and enlarged and embellished by Trajan and succeeding emperors, several of whom occasionally resided there, it having risen to be one of the principal cities of the Roman world. It is supposed that the ancient town was built on the hill of Fourvières, that name being apparently a corruption of the Latin *Forum Vetus*. Among the Roman antiquities still remaining at Lyons are four aqueducts, several cisterns, a theatre, some traces of a palace, and a naumachia.

Christianity was introduced into Lugdunum at a very early period, for towards the close of the second century thousands of Christians were numbered among its inhabitants. The first bishop of the city was Pollinus, who died a martyr in 197, and his immediate successor was Irenæus, the author of a celebrated work on heresies and a native of Lyons, who in 202 also suffered martyrdom, along with no fewer than 19,000 Christian converts. At a later date Lyons was sacked by the Huns and Visigoths, who destroyed many of the noblest of the Roman structures. In the fifth century the city was one of the principal towns of the kingdom of Burgundy, and in the eighth century it was captured by an army of Saracens from Spain, who sacked and destroyed it; but it recovered its prosperity under Charlemagne, and on the dissolution of his empire it became the capital of the kingdom of Provence. Subsequently Lyons fell under the domination of the archbishops of the city, and was long misgoverned by them; but its inhabitants seeking the protection of Philippe le Bel, in 1307, it was annexed to the crown of France. In the twelfth century the sect of the Waldenses was founded by Peter de Vaud, a merchant of Lyons. It was in the thirteenth century that Lyons first began to be distinguished for its manufactures, which either originated with, or received a great impulse from numerous Italian merchants who migrated thither shortly after the city was incorporated with France. In the reign of Francis I., Lyons was fortified with walls, which were destroyed in the Revolution, in 1793, but the city has since been enclosed on the north side with earth-ramparts. During the religious wars in the sixteenth century Lyons suffered severely, and was only recovering from its losses when the Great French Revolution broke out. At the beginning of the struggle the inhabitants enthusiastically supported the revolutionary party, but, becoming frightened at the acts of the central power, they on the 23rd of May, 1793, rose against the republican municipal government and the Jacobin club. The result was that the Convention sent an army of 60,000 men against the city, and after a gallant resistance, which lasted sixty-three days, it was captured. Collot d'Herbois and Couthon wreaked terrible vengeance on the Lyonnese for opposing the revolution. The guillotine was erected *en permanence*, but not satisfied with this method of execution the citizens were mown down in crowds with grape-shot. Great damage was done to the city, and the name of Lyons was abolished, the town being re-christened Ville Affranchie. In 1814 Lyons was the scene of several bloody encounters between the French and the Allied forces, and in 1831, 1832, and 1834 serious riots of the operatives took place there, which were suppressed by the military with great severity.

It was in the reign of Francis I., in the earlier half of the sixteenth century, that the manufacture of silk was first introduced into France from Spain, and in the latter half of that century this branch of industry was zealously promoted by Henri Quatre, who made great efforts to naturalise the silkworm in the country, by cultivating the mulberry-tree in the gardens of the Tuileries, and rearing the bombyx in his own palace. This great monarch established the Rev. William Lee, the inventor of the stocking-frame, at Rouen, and so anxious was he to foster the manufacture of silk, that he offered a title of nobility to every person in his dominions who should successfully prosecute silk manufacture for twelve years. Experience, however, showed that the silkworm could not be profitably bred beyond the line of the Loire. Among the many and great services rendered to France by the celebrated finance minister of Louis XIV., Jean Baptiste Colbert, the measures he devised for promoting the culture of silk deserve to be mentioned. By ordering mulberry-trees to be planted along the high roads in the south, and by offering a premium of twenty-four sous for every tree that was three years old, Colbert soon raised a plentiful supply of food for the silkworm in the south-eastern provinces, and thereby established the cultivation of silk permanently in France. A great increase in the silk manufactures, which were then principally carried on by the inhabitants of Languedoc, speedily followed, and the industry made steady progress till the revocation of the Edict of Nantes, in 1685, drove the great majority of the artisans out of France, and reduced the number of looms employed in weaving silk from 9,000 to 3,000. A long period had to elapse before the silk manufactures of France recovered from this blow, but in 1788, the first year of which we have reliable statistics, 1,600 tons of raw and thrown silk, two-thirds of which had been grown in the country, were worked into fabrics estimated at a total value of £5,000,000. Of this quantity only one-fifth was exported. The French Revolution checked the progress of the silk trade for a time, and proved particularly destructive to the manufacturers of Lyons. There the factories were demolished, and the mulberry-trees in the vicinity were rooted up, the worms perishing in consequence. A local historian with grim humour remarks, that, as the aristocrats had been exiled, "the only remaining use of silk was to make the victorious standards of the armies of France." In 1812 the silk produced in France was only a third of what it had been in 1788, and a far larger proportion of the manufactured silk goods was exported at the later than at the earlier date; but owing to the rise that had taken place in wages and other causes, the lesser quantity represented nearly as great a value as the larger, and the augmented price has ever since been maintained. There were 27,410 looms at work in France in 1812, and their produce was worth £4,300,000.

But a short time previous to the last-mentioned date a great improvement had been effected in the weaving of silk by a native of Lyons, named Joseph Marie Jacquard. This poor artisan was born and bred a silkweaver, but had also been a bookbinder, and a type-founder and cutter, before his eye lighted on a paragraph in an English newspaper stating that the Society of Arts had offered a reward to any one who should invent a machine for weaving nets. Induced to try his mechanical skill, Jacquard in 1802 constructed a loom that effected the purpose,

but thinking little of his invention he laid it aside, and the original machine was either lost or destroyed. But by some means or other the net he had made found its way to Paris, and when he had almost forgotten the piece of mechanism, Jacquard, to his surprise, was one day summoned into the presence of the prefect of the department, who, after questioning him about the invention, and discovering that it could not be found, somewhat peremptorily ordered him to make another. After the expiry of three weeks Jacquard returned with the machine, and a few weeks subsequent he was arrested and dispatched to Paris in charge of gendarmes. There he was introduced to Bonaparte and Carnot, the latter saluting him with the query, "Are you the man who pretends to do what God Almighty cannot do, tie a knot in a stretched string?" Jacquard replied that he could only do what God had taught him to do, and proceeded to explain the working of his machine. The Emperor rewarded the inventor with a pension of 1,000 crowns, gave him employment in the Conservatoire des Arts, and made strenuous efforts to get the Jacquard loom adopted; but this was a task that almost overtaxed his power, and in which he only partially succeeded. The invention encountered great hostility in France, and especially in Lyons, where the Conseil des Prud'hommes broke it to bits in one of the public squares, and denounced Jacquard as a man worthy of universal ignominy. It was in St. Étienne, the chief rival of Lyons in the silk manufactures, that the Jacquard loom was first generally adopted, and when the inventor died in 1834 few of the fruits of his discovery were visible.

In the year 1790 there were 18,000 silk-workers in Lyons, but ten years later, owing to revolutionary disturbances, the number had sunk to about 3,000. Under Bonaparte's rule, however, the silk trade of France rapidly revived, and at the time of the peace of 1814, 12,000 persons were employed in the silk manufacture at Lyons, while during the two following years this number was nearly doubled. In 1828 there were within the city 7,140 establishments for the spinning and weaving of silk, containing 18,829 looms, while seven years later the spinners and weavers of silk in Lyons numbered 27,000. In 1838 the gross produce of the Lyons looms was estimated at a value of 135,000,000 fr., being considerably more than one-half of all the silks manufactured that year in France. By 1864 the value of the silk produced in Lyons had considerably more than doubled, official returns showing that in that year the produce of the looms was worth about 300,000,000 fr., three-fourths of which was exported. The estimated value of the raw material worked up in 1863 was 180,000,000 fr., and the number of looms engaged in the manufacture was then returned at 70,000, two-thirds being in the city and suburbs, and the remainder in the department of the Rhone and the neighbouring departments. There were then 10,000 master silk-weavers in Lyons, and 60,000 workers or *compagnons*, but the latter terms comprise the wives and children of many of the master weavers. As it was calculated that during the same year 70,000 persons were employed in Lyons and the surrounding district in silk culture, in the making of looms, and in other occupations connected with the silk trade, the total number of the people directly and indirectly employed in this industry, in and about the city, would amount to 140,000.

In 1865 the silk goods exported from France were valued at £17,000,000. The raw silk grown in France in 1853 amounted to 26,000 tons, but a disease appeared among the silkworms in that year which rapidly reduced the yield, till in 1865 it was only 5,500 tons. To meet the deficiency in the native crop £10,000,000 worth of raw silk was imported into France in 1864.

In no country in the world has the factory system been developed to the same extent as in England, although it is slowly being adopted in most of the manufacturing and progressive countries in the world.

The great silk manufactures of Lyons are almost exclusively conducted on the domestic system, in the dwellings of the master weavers, who possess from two to six or eight looms apiece, which, with their fittings, are generally their own property. This method has its disadvantages as well as its advantages. It tends undoubtedly to foster independence, but the example of the silk-weavers of Lyons could not certainly be adduced as a proof that it increases the comfort or tends to lessen the toil of the operatives. There the master weaver, and his wife and children, with the assistance of two or three *compagnons* and two or three apprentices, work the looms in one or two rooms in the house set apart for that purpose, and most of the workmen lodge or board with their employers. As a rule the *compagnons* have no settled residence in Lyons, but visit it for a longer or a shorter time according to the demand for their labour; and although they are well fed, they are generally miserably lodged. They are excessively ignorant and improvident, few ever raising themselves out of the condition in which they are born, but they are not more profligate than the operatives in other manufacturing towns. The rate of illegitimacy in some years has been as high as 1 in 3, but, says Mr. McCulloch, "many of the connections out of which these births spring are really but little different from matrimony." In ordinary times the Lyonnese silk weavers work twelve hours a day, but in very busy times their hours of toil are said occasionally to reach the almost incredible stretch of twenty hours. Their physical condition is acknowledged by medical authorities to be low, and they are peculiarly subject to scrofulous and scorbutic complaints, skin diseases and rheumatism, while nearly half the young men of Lyons are exempted from military service on account of weakness, deformity, or shortness of stature. There are between 500 and 600 *fabricans*, or silk merchants in Lyons, who supply the patterns and raw material to the owners of the looms, and who pay them for weaving the cloth, one half of the wages going to the proprietor of the loom, and the other half to the operatives.

Moirés, velvets, and the richest descriptions of silk goods are almost exclusively made in Lyons, which has long been celebrated for the equality and perfection of its fabrics, no less than for the brilliancy of the dyes, and the artistic excellence of the designs. The city comprises among its institutions a great school where 200 students are gratuitously instructed in the various branches of drawing, and in designing, and where they are also taught the "*mise en carte*," or the art of adapting the designs to the loom. This school may account for the superiority of the patterns produced at Lyons. Among the minor manufactures of Lyons, the most important are nets, cotton goods, blankets, hats, books, gold and silver lace, earthenware, liqueurs, and drugs. There are about 80 hat-making establishments in the city, producing an annual total of 450,000 hats. The population of Lyons in 1862 was returned at 318,803; ten years previous it only amounted to 156,169.

Lyons contains an extraordinary number of buildings, remarkable either from their historic associations, or on account of their magnificence, and there are no fewer than 70 squares or *places* in the city. The Place Bellecour (formerly Louis le Grand), in the heart of the city, is one of the largest and finest squares in Europe. In the Place des Terreaux stands the Hôtel de Ville, originally built in 1646 and 1655, and restored in 1863, one of the finest buildings of the kind in France. Here De Thou and Cinq Mars were beheaded. The cathedral, on the slope of Fourvières, is in the Gothic style of the time of Louis XI., and higher up stands the Church of Notre Dame, on the site of the *Forum Vetus* built by Trajan. Beneath the sacristy of the Abbey of Ainay, and penetrating below the bed of the Saône, are gloomy dungeons in which many of the early Christians are believed to have been confined previous to suffering martyrdom. The public Library of Lyons, which occupies a portion of the college buildings on the Quai de Retz, is the best provincial collection in France. The church of St. Irenæus is an uninteresting modern structure, but it is built on the grave of the martyred bishop, and beneath is a crypt in which Polycarp, who had conversed with the apostles, is said to have preached at the age of eighty-six, and where thousands of Christians are believed to have been massacred in 202, in obedience to the orders of Septimius Severus. The hospitals are the largest public buildings in Lyons. The Hotel Dieu is the most ancient establishment of the kind in France, having been founded by Childebert and his queen at the beginning of the sixth century. It accommodates 12,000 in-patients annually, besides affording relief to many outside the walls. The Hospice de l'Antiquailles, for syphilitic and insane patients, occupies the site of the Roman palace on the hill of Fourvières, where the Emperors Claudius and Caracalla were born. There are as many as a dozen other hospitals in Lyons. Among the remaining buildings worthy of notice are the Palais des Arts, the Prefecture, and the Palais du Commerce et de la Bourse; and Lyons has also a fine botanical garden situated within the city, near the principal manufacturing quarter.

Owing to the irregularity of the ground on which it is built, Lyons could hardly have been laid out with much regard to uniformity, but its natural disadvantages in this respect have been considerably aggravated. The streets are in many cases very narrow, and lined with houses of so great a height that they exclude the light from the thoroughfare. Lyons has got the reputation of being one of the dirtiest places in Christendom; but it, of course, can boast of quarters where the houses are not merely clean, but very tasteful and sumptuous. Many of the streets are too steep for carriage traffic, while others lie very low. The Rhone is liable to sudden inundations which have frequently done great damage, as in 1840 and in 1852, when some of the bridges were carried away and a considerable part of the city and neighbourhood was laid under water. There are nineteen bridges upon the two rivers, and the quays of Lyons, which number twenty-eight, are said to be the most remarkable in Europe. At Lyons the roads from Paris, Marseilles, Bordeaux, and Geneva, from Switzerland, Italy, and Auvergne all meet; and by means of the Rhine and Rhone canal it communicates with the Rhine, while other canals, branching off from its rivers, connect it with the interior of France. The railway communication to all parts of the country is also very complete. In the reign of Henri Quatre, Lyons was called "the golden gate of France;" it is now sometimes styled "the French Manchester."

MUSEUMS: THEIR CONSTRUCTION, ARRANGEMENT, AND MANAGEMENT.

BY SAMUEL HIGHLEY, F.G.S., ETC.

I.—THE AIM OF INTERNATIONAL, NATIONAL, LOCAL, AND SCHOOL MUSEUMS.

THE object of the following series of papers under the present heading will chiefly consist in discussing the requirements of local and school museums, for as yet no recognised type of construction, or system of classification, or list of objects essential to their limited aims, has been established; but for the better appreciation of the grade such institutions should occupy, it will be necessary to discuss the requirements of museums having wider or special aims, such as embrace international and national collections.

International Museums, or "Exhibitions" as they are by custom termed, may be regarded as the arena of a technical tournament wherein all nations enter the lists in peaceful competition for the honour of achieving the greatest amount of progress within a given period in the various departments of manufacture, science, and art. In such museums the native products, mineral, vegetable, and animal, the objects of manufacture, educational appliances, scientific and mechanical inventions, and works of art of all nations should find a place, care being taken to exclude all objects that would only possess an advertising value to their exhibitors, while the works of the conscientious designer and producer should meet with every consideration and due acknowledgment or reward, to stimulate to fresh efforts and progress in the civilising arts. The aim, to mete out fair awards or due acknowledgments to the ingenious, artistic, and enterprising, who contribute to such exhibitions, involves a problem that has received great attention and grave discussion, a problem that embraces the constitution and election of juries—the award of medals *versus* certificates of having been admitted to exhibit (1871), and the right of appeal against jury awards—questions to which answers were given *pro* and *con* by the principal exhibitors of 1862, in the Society of Arts' "Report on Awards of Merit at International Exhibition," published in 1863, from which may be deduced the general opinion, that the chairmen of juries should be men of position, having experience in the departments over which they preside, combined with judicial acumen and firm will, and should be elected by the State Commissioners of an exhibition; while the juries should be constituted of men of special *practical* experience for each section of a class, free from all trade influences, and willing to devote time, care, and an unbiassed judgment to their important and delicate office, and should be *nominated* by the class committees (formed of exhibitors), and the necessary number *elected* by the exhibitors of each class; that the secretaries of juries should be paid officers; that the juries should examine the contributions of every exhibitor, in his presence, or formally enter upon the minutes of their proceedings the reason why an examination could not be made, and should not, on the one hand, take for granted, that articles exhibited by old established or well-known firms *must* receive award, or, on the other hand, ignore the productions of unknown men—in other words, should not pass judgment on names instead of things; that there should be a right to appeal against the decision of juries, in the event of neglect of proper examination, misconception of the object, etc., and against an award being made to an article, where it could be shown its exhibitor was neither its designer nor manufacturer, so as to secure the elimination of the mere shop-keeping element;* that the honorary office of juror should be acknowledged by the conference of a silver "juror's (class) medal" to those only who had conscientiously fulfilled their duties, tested by regular attendance; that a bronze prize medal, engraved with name and class, should be awarded to every exhibitor whose contributions were worthy of recognition, to stimulate both brain and pocket for the production of novelties, as without such inducement to attain distinction there would be no encouragement to exhibitors to enter into greater expenditure than was just necessary to keep their names and specialties before the public, so that exhibitions would tend to degenerate into mere advertising mediums, instead of being complete illustrative records of progress made in manufactures, science, and art, since the previous contests of nations.

As most of our readers are probably aware, the experiment of holding international exhibitions annually proved a failure. To give the experiment a fair trial, it was resolved to hold an exhibition every year for ten years. The amount of public encouragement and support the project met with was, however, so inconsiderable, that H. M. Commissioners did not feel justified in continuing it, and the International Exhibition of 1874 was therefore the last. The following were some of the rules and regulations in connection with these exhibitions, and they will still be of general interest.

The fair award of prize medals involved many intricate questions, so Her Majesty's Commissioners for the Exhibition of 1871 attempted to solve the difficulty by dispensing with medals altogether, but, as an equivalent honour, gave to each exhibitor "a certificate of his having obtained the distinction of admission to the Exhibition," their aim being to secure a select collection of specimens remarkable for excellence, novelty, invention, cheapness combined with good workmanship, etc., especially of such improvements or objects as have been designed since the Exhibition of 1862. To attain this select character, rather than the bazaar-like displays of previous exhibitions, where any contributor was left to fill the space allotted to him in any manner he thought fit, all objects must be submitted to a "committee of selection" (which take the place of the juries) appointed for each class or sub-class, formed of "competent judges," who will determine whether they "are of sufficient excellence to be worthy of exhibition;" further, the number of specimens from each producer will be limited to those which are deemed absolutely necessary, consequently duplicates of any object will not be admitted. To save space and preserve uniformity of aspect throughout the exhibition galleries, the Commissioners will in future provide glazed cases, fittings, stands, steam and water power, and general shafting; also (except in the case of machinery) attendants, free of charge to the exhibitors; and, moreover, the necessary explanatory labels, furnished from the official catalogues, which will be of a more detailed character than those issued on previous occasions. Further, to reward and do justice to the efforts of the thinkers and workers in the great hive of commerce, the official catalogues will contain "a biographical index of all the artists and producers, which will give the particulars of the history of each one, and serve as a permanent record, or Domesday-book, of all who have taken an active part" in international exhibitions, and the honours they have thereat attained.

* In exceptional cases mere dealers in other people's manufactures and designs might receive "honourable mention" for artistic taste, judgment in selection, etc., if it were not considered that "the public are the best judges" (see Society of Arts' Report) as to the value of the displays of non-manufacturing exhibitors, and public opinion sufficient reward.

APPLIED MECHANICS.—XIX.

BY ROBERT STAWELL BALL, M.A.,
Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.

MACHINERY USED IN SPINNING OF COTTON (*continued*).

In our last paper on this subject we gave a description of the bobbin and fly-frame, and the principle on which it acts in giving a twist to the sliver as it emerges from the rollers. In order to illustrate the working of this engine let us consider an example taken from Ure.

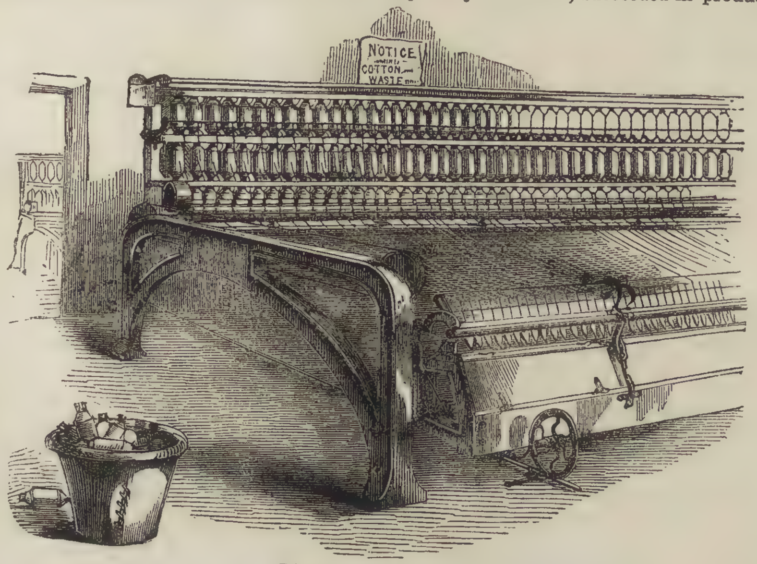


Fig. 6.—THE MULE.

Let it be assumed that the drawing rollers deliver in 10 seconds 45 inches of roving, and that this length receives 30 twists; the spindles must in consequence make 30 revolutions in 10 seconds, and the bobbins must turn with such speed that they wind up the 45 inches in 10 seconds. The diameter of the bobbin barrel being $1\frac{1}{2}$ inches, its circumference is, of course, $4\frac{1}{2}$ inches, and it must make 10 revolutions more in the same time than the spindles. The effective speed of the bobbins will be thus $30 + 10 = 40$ turns in 10 seconds. Should the bobbins increase to 3 inches diameter by the winding on of the sliver, they will take up 9 inches at each turn, and consequently 45 inches in 5 turns; their speed should, therefore, be reduced to $30 + 5 = 35$ turns in 10 seconds. In general the excess in number of revolutions which the bobbins must make over the spindles is inversely as the diameter of the bobbins. The speed of the bobbins must remain uniform during the period of one ascent or descent upon the spindle, and must diminish at the instant of changing the direction of the up and down motion, because a fresh range of convolutions then begins with a greater diameter. When, for example, 30 coils of the sliver or rove are laid in one length of the bobbin barrel, the bobbin must complete its vertical movement up and down within 30 seconds in the first case above mentioned, and within 60 seconds in the second case.

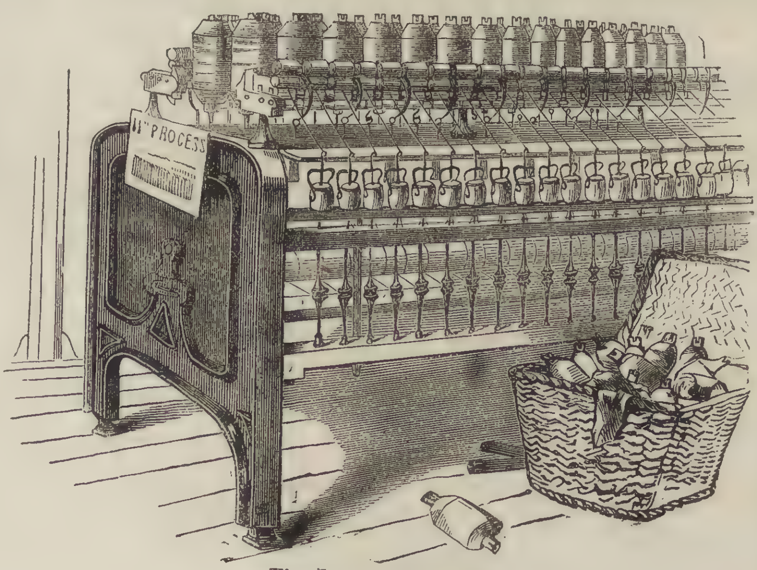


Fig. 7.—THE THROSTLE.

The machines by which the yarn is finally spun in a cotton mill are analogous in principle to the machines we have just described, the essential features being drawing and twisting by the combination of which the sliver which originally came from the carding machine is reduced to the finest thread. The machines are of two different characters: in one, the throstle, the twisting and winding are carried out simultaneously; in the other, the mule, the thread is first stretched, and then the final twist is imparted. This machine is the glory of the English cotton manufacture. Figs. 6 and 7 represent the mule and the throstle, by means of which Arkwright and Crompton, especially the latter, succeeded in producing yarns of sufficient strength, although of excessive fineness and tenuity, to be employed in the manufacture of the delicate cotton fabrics which we know under the name of muslins.

By the old spinning-wheel only a single yarn could be produced from its single spindle, and this yarn, though strong enough for the weft or cross threads of a woven fabric, was not suitable for the warp or long threads, and for this linen yarn was long used by the early manufacturers. The yarn produced by Hargreaves' spinning-jenny was neither stronger nor better in quality than the yarn made by the old spinning-wheel; but as the number of spindles employed was at first eight, and ultimately eighty, by the introduction of subsequent improvements, a considerable saving of labour was effected, and the production of cotton yarn was consequently rendered less costly. The great fault of the yarn produced by the spinning-jenny was its want of fineness, but a greater degree of tenuity was at last obtained by Arkwright, in whose spinning-frame the principle of drawing out the rove between rollers was first introduced. This principle, and the peculiar construction of the rollers, we have already described in the previous paper. This drawing or attenuating the rove between two pairs of rollers revolving with different degrees of speed was the essential principle of Arkwright's original spinning-frame, which was set in motion by the application of water-power, from which the yarn it produced obtained the name of "water twist." In Hargreaves' spinning-jenny the principle of stretching the rove in its passage from one set of spindles to another had been introduced, and this it will be necessary to bear in mind when we come to speak of the mule.

The transition from Arkwright's spinning-frame, or water-frame as it was also called, to the throstle-frame was easy enough, for the latter was merely an augmentation or extension

of the former. The principle is entirely the same, but a far greater number of spindles were introduced, while the movement of the parts was simplified, and the speed of the machine increased. By these means a much greater amount of work was obtained with no more expenditure of power than was necessary to keep the original water-frame in motion. A fineness of 80 hanks to the pound was attained by the water-frame and throstle-frame; but it has been generally found necessary in throstle-spinning to limit the number of hanks to the pound to 40 or 50, because finer yarn is not possessed of sufficient strength to bear the drag of the bobbin. The throstle-frame derives its peculiar name from the similarity of the noise it makes in working to the singing of the throstle or thrush.

The mule, or mule-jenny, invented by Samuel Crompton, was so called because it partook equally of the characteristics of the spinning-jenny of Hargreaves and the water-frame of Arkwright. The former stretched the roves, and the latter drew them out between rollers to a greater degree of fineness; but the mule did both, first drawing the rove and then stretching it. This produced a greater uniformity in the yarn throughout its length, and thus rendered the twist more equable. The mule also possessed an advantage over the throstle-frame, in being without bobbins, the yarn being wound on the spindles without being subjected to any strain. The ordinary mule of Crompton requires an attendant spinner, to return the carriage to the rollers after the mule has disengaged itself from the parts of the machine by which it has been driven, when the drawing, stretching, and twisting of the thread during a single operation of the machinery has been effected. The self-acting mule, invented by Mr. Roberts, dispenses with the services of an attendant, the carriage being caused to return to the rollers by purely mechanical means, children only being required to watch the progress of the machines for the purpose of joining threads that may have been accidentally broken in the stretching.

NOTABLE INVENTIONS AND INVENTORS.

XXI.—GLASS-MAKING (*concluded*).

BY JOHN TIMBS.

THE Bohemians were formerly very celebrated for their extensive glass works. They imitated the Venetians in their curious method of ornamenting glass-ware, which has since become well known, and was at one time much in repute in England. In making the stems of wine-glasses and goblets, they enclosed white and coloured enamel tubes, twisted together with colourless transparent glass. The Venetians also originated the modern style of glass engraving, which afterwards extended through all the glass-making countries of Europe. The first specimen was scratched with a diamond, or broken steel file; but the engravings produced by copper and lead wheels on the lathe are far superior. With few exceptions, the design was a roughed surface *intaglio*, which, contrasted with its white transparent ground, had a lace-like delicacy of effect, especially if improved by traced polished lines occasionally introduced to give relief of light and shade. A beautifully engraved vase, by a Bohemian artist, was in the possession of the late Mr. Pellatt; the workmanship is more elaborate than even that of the Portland vase; the subject is from Le Brun's painting of the conquest and final overthrow of the Persians, at the battle of Arbela, by Alexander the Great. For depth of workmanship and artistic execution, as a modern intaglio engraving, Mr. Pellatt considered this vase unrivalled. The Venetians and Bohemians had cylindrical drinking-glasses curiously painted in vitrified colours, with coats of arms, called *vidrecome*.

Bohemia was the first to emancipate herself from the Venetian monopoly. Her forests afforded fuel and potash in abundance; and silex and lime of excellent quality were to be found in the immediate neighbourhood of her existing works, and probably led, in the first instance, to the introduction of an improved system into that country. The Bohemian proprietors supported the manufacture, and even embarked in the trade themselves, and by this means they brought into the market a beautiful article of commerce. The Venetian origin of their craft is plainly seen in the present day in the reticulated pattern, the Eastern form, the taper stem, and the variety of colours. Their colours and engraving, and imitations of precious stones, are likewise very beautiful, but still are an imitation of Venetian art.

The application of glass to the glazing of windows is comparatively of modern introduction, at least, in Northern and Western Europe. In 672, artists were brought to England from abroad, to glaze the windows of the Monastery of Weremouth, in Durham: such was the change made in the churches by the use of glass, that the unlettered people avowed a belief, which was handed down as a tradition for many generations, that "it was never dark in old Jarrow church." In 1567, glazing was by no means common in mansions: we read of the glass casements of Alnwick Castle being taken down during the absence of the family to preserve them from accident. A century after, in Scotland, only the upper rooms in the royal palaces were furnished with window-glass.

The first English glass-houses for the manufacture of fine glass were those of the Savoy and Crutched Friars, established about the year 1557, when the Friars' Hall was converted into a glasshouse for making drinking-vessels. The finest flint-glass was made at the Savoy. Plates for looking-glasses and coach-windows were first made in 1670, by Venetian artists, under the patronage of the second Duke of Buckingham at Foxhall (Vauxhall) with great success. The works stood on the site of Vauxhall Square: some of the finest "Vauxhall plates" are to be seen in the Speaker's state-coach. The Falcon glass-house, Holland Street, Blackfriars Road, occupies the site of the tide-mill of the old manor of Paris Garden, and has existed more than a century. The English manufacturers were, however, long inferior to the Venetian; for in 1685, nearly a hundred years later, Sir Robert Mansel obtained a monopoly for importing the fine Venetian drinking-glasses, such as were not brought to perfection in England till the reign of William III. "Our glass manufacture," says Mr. Pellatt, "has since made rapid progress, and the white crystal glass-works of England indisputably excel, at this moment (1849), those of any other country. The essential and distinguishing qualities of good glass are its freedom from specks or striæ, and its near resemblance to real crystal in its brilliant, pellucid, refractive, and colourless transparency. In all these respects, the productions of the British glass-houses are at present unrivalled."

The incrustation of figures in glass has been perfected in England: by the crystallo-ceramic process, arms, ciphers, portraits, and landscapes are enclosed with glass so as to become chemically imperishable; the less fusible ornaments are introduced within the body of the glass, while the latter is hot, by which means the air is excluded, the incrustation being actually incorporated in the glass; it is of a white, silvery appearance, which has a superb effect when enclosed in richly-cut glass. Casts of medals and coins, and inscription plates, are thus incrusted for ages to come. Casting glass by machinery has been introduced into England from the United States of America, and ornamental skylights are moulded in strong flint-glass.

We now proceed to describe briefly the details of glass manufacture. It is important to bear in mind that the basis of glass, at all times and in all countries, is the same—silex or flint, and alkali, two apparently opaque bodies, which by fusion become transparent. There are five distinct kinds of glass: (1) Flint-glass, as crystal; (2) crown-glass, or German sheet glass; (3) broad glass, or common window-glass; (4) bottle or common green glass; (5) plate-glass. The silex now used in this country for glass-making, is that of sea-sand; the port of Lynn, in Norfolk, and Alum Bay, in the Isle of Wight, having long furnished the greater portion of the silex. Flint-glass derives its name from flints, calcined and ground, having been formerly used for it. The alkali employed for making flint-glass is pearl-ash. Barilla, kelp, and wood-ashes are used for inferior kinds of glass; the impurities even assist towards fusing the silex. Coarse alkaline substances all contain iron in some degree, and to the presence of this metal is owing the green colour of common glass. The alkali acts as a flux, and facilitates the vitrification of the earthy particles, which separately are unvitrifiable; and gives to them a pliability when hot, which admits of their being blown, wrought, extended, and even hammered. It is remarkable that the glass found by Mr. Layard at Nineveh, now in the British Museum, bears the marks of having been turned, a process which, though possible, is seldom attempted by modern artists, though the

application of the grinding tool, fixed on a lathe, approaches to the practice.

Flint-glass is the most brilliant, and the heaviest, owing to the large quantity of oxide of lead which it contains, the greater density which it imparts to glass giving a greater power of refracting the rays of light, and hence its importance for optical purposes. Manganese (*glass soap*) clears the glass of all colouring matter; and nitre, in a small proportion, is used. The importance of lead is well understood in England, and to the attention paid to its preparation and quality is one cause of the excellence of British flint-glass. The oxide is minium or litharge. Flint-glass, of not less than the usual density of 3·200, well polished by the lapidary, is considered the nearest approach to the diamond.

The ingredients, being mixed, are put into the crucibles, or pots, previously placed in the furnace. Very strong and long continued heat is necessary, not only for the perfect fusion and amalgamation of the materials, but also for the discharge of the impurities which they contain. When these have been thrown off, and the glass, or *metal*, appears colourless and translucent, the vitrification is known to be complete. The temperature of the furnace is then lowered, until the glass is less fluid, and of a *pasty* character, sufficiently consistent to be tenacious, but soft enough to yield to the slightest pressure without cracking or losing its tenacity. This vitrification usually occupies about forty-eight hours; and you see fashioned flint-glass, a substance proverbially brittle, blown with the human breath, pulled, twisted, cut, and then joined again with the greatest facility. The tools with which all these operations are performed are of the most inartificial description, and do not appear to have received any improvement from the earliest records of the manufacture.

Glass of every kind would be so brittle as to crack and break at every comparatively small variation of temperature, if it were not subjected, immediately after it is fashioned, to *annealing*, that is, heating before the point at which it softens; the glass being gradually removed from the hotter to the cooler parts of the furnace.

Crown-glass is the best description of window-glass, without any mixture of metallic oxide, and is made by blowing in circular plates. *Broad-glass* is an inferior kind of window-glass, made with a cheaper kind of alkali.

Bottle-glass is of still inferior quality. It is hardly possible to convey a correct idea of the manipulation of a bottle of the simplest form. The tools used are an iron tube, about five feet in length; a few instruments like shears, and stamps with a strawberry-shaped die. The workman first dips the end of the tube into the pot of molten glass, twisting it round so as to take up enough glass for the required bottle; after a few turns of the rod, and a breathing or two into it, a hollow ball appears at the end, which is shaped by the shear-like instrument as it is rotated on the glass-maker's chair, and a *pontil* is then attached opposite to the tube, which is next broken off. By re-heating in the furnace, the mouth of the bottle is formed; a boy then brings up on the end of a rod a small portion of ruby, aqua marina, or any colour required to ornament the bottle. With this he touches the neck of the bottle which is rotated in the chair by the glass-blower. Between these rings little lumps of coloured glass are then stuck on, and stamped as strawberries with the die. During this operation the bottle has to be several times introduced into the furnace. Lastly, the finished bottle is annealed.

Newcastle has always been celebrated for its glass bottles, and since 1845 the produce has increased fourfold. During 1862, there were 47 bottle-houses in operation on the banks of the Tyne, the Wear, and the Tees, and their produce was about 4,230,000 dozen.

Plate-glass was first cast in this country in 1773, when a company established works upon a large scale at Rawenhead, near Prescot, in Lancashire, which are still in operation. Plate-glass is also blown. The ingredients are the purest and whitest sand, and soda produced by the decomposition of common salt and lime; manganese and oxide of cobalt being added for discharging the colour; and a large proportion of broken plate-glass, or *cullet*, is used. When the materials are reduced in the furnace to the proper state of fusion and vitrification, the glass is transferred from the melting-pot to a large vessel called the *cuvette*, and allowed to remain some hours in the furnace, to rid it of air. The cuvette is then withdrawn from the furnace, and raised and suspended by a crane, while the contents flow out, and are distributed upon the table by a roller. The casting of large plates of glass is one of the most beautiful processes in the arts; the large mass of melted glass, rendered luminous by heat, which is poured forth, exhibits changing colours after the roller has passed over it. This operation is conducted with celerity and in silence. The plates are then placed upon the floor of the annealing-oven, the door is closed, and its crevices are stopped, to ensure the gradual cooling of the plates, which usually takes a fortnight. The plates are then withdrawn, squared, and ground and polished by steam-machinery. The plates are sometimes of very large size. In August, 1871, a plate of glass, measuring 100 superficial feet, underwent the process of silvering at the works of Pratt and Co., Peaseley Cross, St. Helen's. This is said to be the largest mirror ever turned out of any establishment in Lancashire, and, with one or two exceptions, the largest ever done in England. The silvering was accomplished by the new process, by which the mirror is completed in about forty hours, instead of occupying ten days.

Rough plate-glass, not transparent, is made by Hartley's patent, by ladling rough glass directly on to a hot table near the melting-pot, in place of carrying it as heretofore out of the refining-pot to a cold table at some distance from the furnace. By this means rough plate-glass is made in minutes, instead of hours or days; and in patterns stamped by the table, which is so hot as to keep the glass molten, so that one ladle-full can be added to another, and imperceptibly joined to it, thus admitting of the formation of plates of any size. One glass firm is stated to have expended £25,000 in vainly endeavouring to use the ladle and to draw the table close to the rough melting-pot.

Malleable Glass.—M. Peligot has called attention to this new fact—that he has discovered the devitrification of a piece of St. Gobain glass, prepared a long time ago by M. Pebouze; the glass had lost its transparency, but not its density. Placed in a drawer, the piece of glass, supported by one extremity, was found after some days curved under its own weight, it having become a malleable glass; the surface also was covered with efflorescence. Pliny speaks of a glass that could be bent and unbent; and the story goes that Richelieu ordered an inventor to be put to death for proposing to divulge a process for making malleable glass.

Soluble Glass and *Water Glass* are the names given to soluble silicate of soda, which, in contact with lime, consolidates, and is partly converted into silicate of lime. Silicate of soda not only consolidates, but combines with porous sandstone or limestone, forming a compact mass of flinty hardness impervious to atmospheric influence. The soluble silicate has also been employed as a protecting varnish for out-door fresco-paintings in Berlin.

Soluble glass is described by M. Sauzay as obtained by melting in a refractory crucible a mixture of ten parts of potash, fifteen parts of quartz finely pulverised, and one part of charcoal powder. When it is melted, the glass is cast; it is afterwards pulverised and treated with four or five times its weight of boiling water. A solution is thus obtained which, applied to other bodies, dries rapidly in contact with the air.

Glass-working, in its simpler adaptations, is of easy acquisition. Even cold glass may be worked with a facility known to few. It may be drilled in holes by the common watchmaker's drill-stock. A steel drill, of good quality, well hardened, will do the work perfectly; and should the edge of the tool give way before the hole is pierced through, a little emery powder and oil will remove any difficulty; or, with the help of these, the hole may be bored with a copper drill. Not only so—glass may even be turned with a lathe.

The delicacy and accuracy of the chronometer require the aid of glass; while the common green bottle-glass can be manufactured cheap enough for casting conduit pipes, for chemical uses, or water-supply. No chemical test is so delicate as a mass of fused flint-glass; it will detect the presence of metallic colouring matter, especially iron, though the most carefully conducted analysis may fail in discovering the slightest trace of it. Josiah Wedgwood found that $\frac{1}{20000}$ part of gold would give a rose-coloured tint to flint-glass. (See Pellatt's "Curiosities of Glass-making," with details of processes and productions, coloured illustrations, small quarto, 1849.)

TECHNICAL DRAWING.—XLV.

DRAWING FOR MASONS.

Fig. 414 is the elevation of a semi-cylinder arch, the planes of which are vertically parallel, and at right angles to the axis. No difficulty will be experienced in drawing this figure, the form of the arch under these conditions being a semicircle, the joints of the voussoirs converging to the centre.

Fig. 415 is the plan of the whole structure.

Fig. 416 is the sectional elevation, caused by a plane standing on the axis in the plan, thus giving a complete section of the keystone, and leaving the intrados of the arch in elevation.

Fig. 417.—This figure is a development of the intrados of the arch. The student is reminded that to obtain this, the entire forms a most easy step. This system—if, indeed, anything so simple can be called a system—is much used on the Continent, and at once recommends itself to working men from the ease with which solidity is given to otherwise flat elevations. To speak of *theory* is out of the question; the best teaching will therefore consist in the practice.

Fig. 418.—Let *a b c d* be a correct copy of the end elevation of the keystone, as in Fig. 414, the arc *a b* being struck with the radius of the arch *o a*, and the sides of the voussoir being produced to *o*, so as to form a complete wedge.

Now, placing the T-square so that its cross end may work against the left side of the drawing-board, draw the lines *c c′* and *d d′* by means of the set-square of 45°, set off on *d* and *c* the real depth of the block by scale, and join *c′ d′*.

Fig. 414.

Fig. 416.

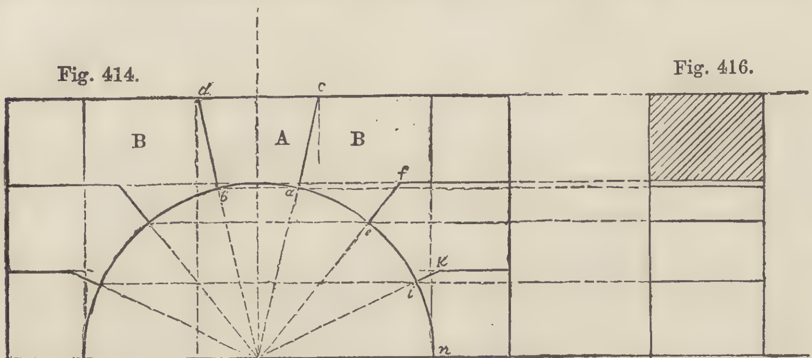


Fig. 415.

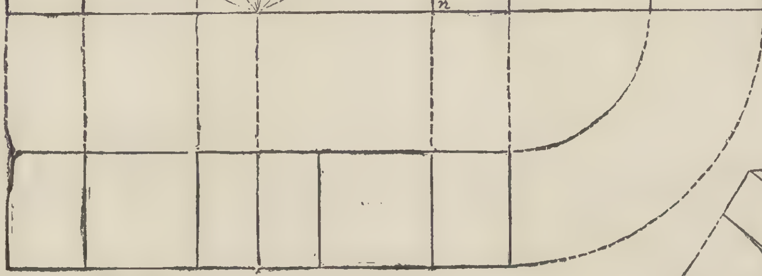


Fig. 419.

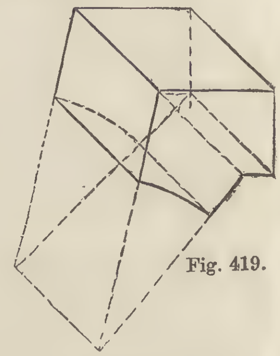


Fig. 418.

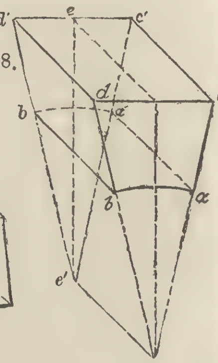
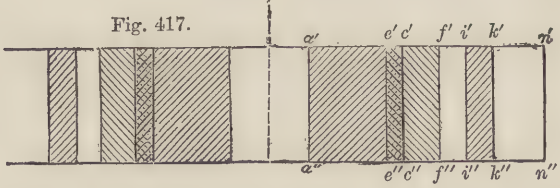
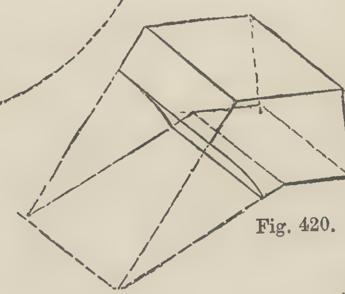


Fig. 420.

Fig. 417.





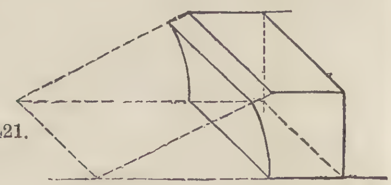


Fig. 421.

curve must be divided into a number of parts, and these set off along a straight line.

Another important lesson is, however, given in this—viz., the method of obtaining the exact shape of the templets for the sides of the various voussoirs—a matter of very great importance in stone-cutting—each laid down flat on the line at which it would meet the intrados.

Having found this place *a′ a″*, measure the exact length of the side of the voussoir in the elevation, viz., *a c* (the line common to the keystone and the first voussoir), and set off this length on the plan from *a′*—viz., *a′ c′*—and draw *c′ c″*; then the rectangle *a′ a″ c″ c′* is the shape of the templet required for the two sides of the keystone A, and one side of the voussoirs B, B; the templets for the other voussoirs are obtained in the same manner.

Figs. 418, 419, 420, and 421 are simply projections of the various voussoirs. These are delineated by a method even simpler than isometrical projection, to which study practice such as this

Find *e*, the middle of *c′ d′*, and from *e* draw a perpendicular. From *o* draw a line parallel to *d d′*—viz., *o e′*. Draw *c′ e′*, *d′ e′*, which will give the distant end of the wedge.

From *e′*, with radius *o a*, describe the arc *a′ b′*. This will complete the keystone.

The other voussoirs (Figs. 419, 420, and 421) are delineated in the same manner, and will be easily understood from the plate.

The examples next given form applications of the previous lesson, and give the principles of the lines concerned in a groined roof called, in French, *voûte en arc de cloître*.

Fig. 422 is the plan of an oblong chamber, Fig. 423 (A B C) is the transverse and Fig. 424 (A′ B′ C′) the longitudinal section, the section at the groin being shown on one of the diagonals.

It will be seen that the extrados in Fig. 423 is eccentric. The method of drawing this has already been given in previous lessons.

The points of division of the voussoirs (F, G, H, Fig. 423) having

been projected on the diagonal of the plan, viz., *f*, *g*, *h*, and from these to the longitudinal section, viz., F′, G′, H′, etc., the next process is to find the joints in this semi-elliptical arch.

For this purpose it is necessary to find the *foci* of the semi-ellipse.

From the points *f′*, *g′*, *h′*, *b′* in the extrados of Fig. 423, draw lines parallel to the base-line, and cutting the line X Y in 1, 2, 3, 4.

From X, with radius X 1, X 2, X 3, X 4, describe quadrants, cutting the line W X in 1′, 2,′ 3′, 4′.

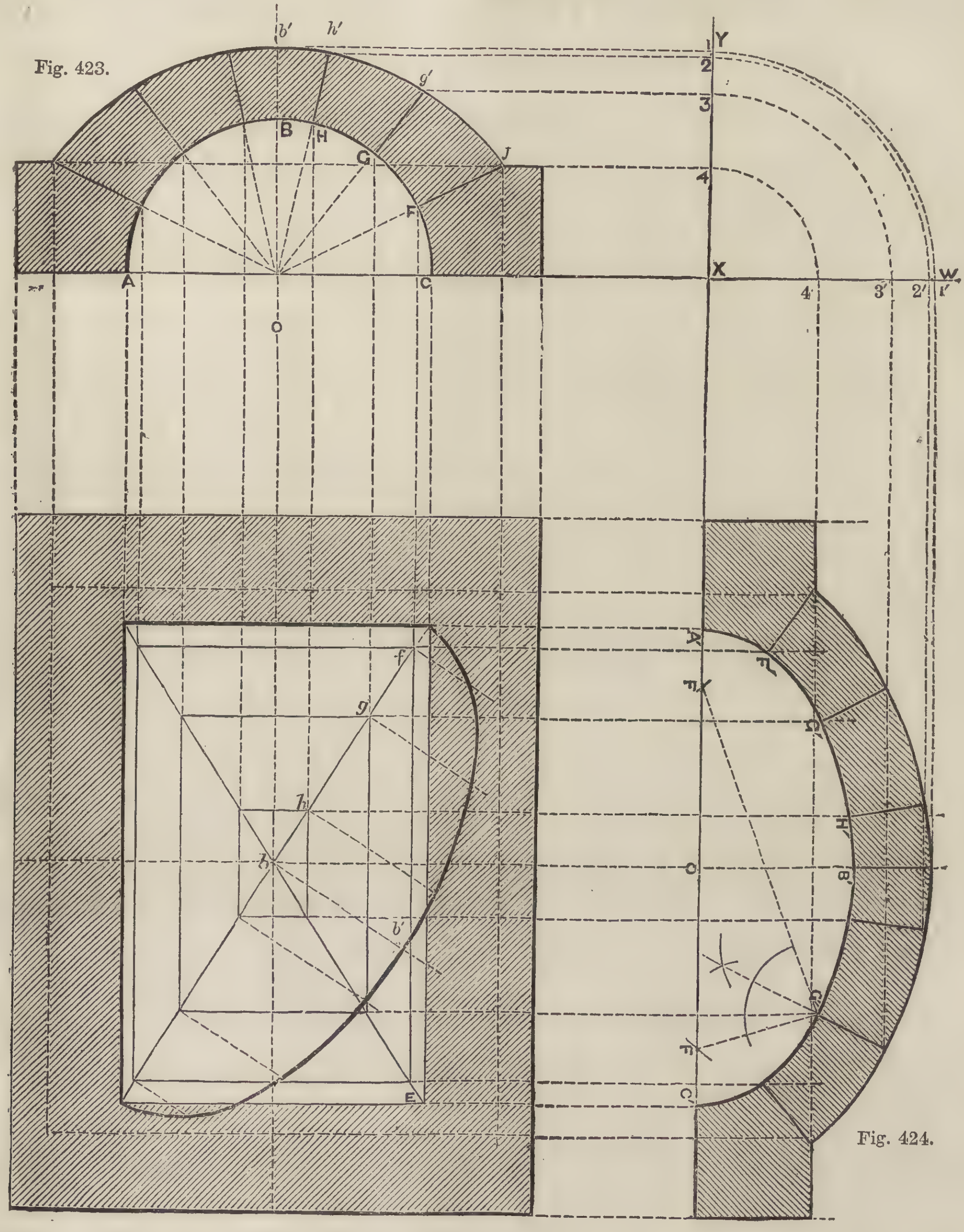


Fig. 423.

Fig. 422.

Fig. 424.

A′ C′ is the long diameter, and O B′ is half of the short diameter.

From B′ (the extremity of the short diameter), with the length O A′ (half of the long diameter), describe arcs, cutting A′ C′ in F, F, the foci of the ellipse.

From both foci draw lines to each of the points of division, as shown at G″, and bisect the angles thus formed. The bisecting lines will be the required joints.

Now, to terminate these by the extrados, produce the base-lines of Fig. 423 and Fig. 424, intersecting each other in X, and forming the right angle W X Y.

From these points draw lines parallel to the base-line of the longitudinal section, which, cutting the lines forming the divisions of the voussoirs, will give the points through which the extrados is to be drawn.

In making these drawings, as in making all drawings of a similar character, great attention must be paid to correctness of detail and general manipulation, as we have often urged before. Although the repetition of this caution may be needless for some, it is applicable to a great many. A single error of trifling magnitude may render many hours of labour abortive, and it is to guard against this that we repeat our caution.

PRINCIPLES OF DESIGN.—XXII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

POTTERY AND HOLLOW VESSELS.

In this chapter I have to commence our consideration of pottery, and of hollow vessels especially; and this I do with considerable pleasure, as works in pottery enjoy a longer existence, though, through the character of the material of which they are made, they are more fragile than those formed of almost any other substance. Many works of Greek pottery are known to us, and not a few such works by the ancient Egyptians, and these are preserved not as fragments merely, but as works in their entirety, and with the same beauty that they possessed when first they left the hands of the potter.

Clay is a most desirable material with which to form works of utility and of beauty, and this for many reasons. First, it is so inexpensive, as to be almost valueless; secondly, it is easily formed into vessels of almost any required shape; thirdly, it is capable of being "worked" into shapes of great beauty by a momentary exercise of skill; fourthly, clay is naturally of many beautiful colours; fifthly, it is capable of receiving by application to its surface any amount of colour, and of preserving such colours as are applied to it in an unimpaired state for ages; and sixthly, it is susceptible of the highest art-finish, or the bold sketchy touch of the modeller's hand. I say that clay is a very desirable material for the formation into vessels of various kinds, because of its inexpensive character. This quality of cheapness gives to the material an advantage over many other substances of a much more costly character, such as should not be overlooked, for the long existence which so many works of earthenware have had is mainly due to the worthlessness of the material of which they are composed. In my first chapter I gave an extract from the writings of Professor George Wilson, showing that gold and silver, while beautiful in themselves, and worthy to be fashioned into exquisite devices, are yet too tempting to the thief, and to all who are pressed for means, to remain long in the form of art-works. Families who have been reduced in circumstances, and have thereby been constrained to part with their old plate, have melted it, so as to hide their shame. To illustrate this, let me quote from the "Handbook of the Arts of the Middle Ages and Renaissance, as applied to the Decoration of Furniture, Arms, Jewels, etc., translated from the French of M. Jules Labarte, 1856." After giving the names of many workers in the precious metals, the author says:—"We may form some idea of what artists these Italian goldsmiths were of the fourteenth, fifteenth, and sixteenth centuries, and what admirable works they must have produced. But, alas! these noble works have almost all perished; their artistic worth proving no safeguard against cupidity or necessity, the fear of pillage, or the love of change. But a very few names even of those skilled artists have descended to us, and in making known those preserved to us in the writings of Vasari, Benvenuto, Cellini, and others, we can rarely point out any of their works as being still in existence.

"Cellini tells us that while Pope Clement VII. was besieged in the castle of St. Angelo, he received orders to unset all the precious stones that were upon the tiaras, the sacred vessels, and the jewels of the sovereign pontiff; and to melt down the gold, of which he obtained 200 pounds. How many artistic treasures must have perished in the crucible of Cellini." We now see clearly that while clay is a much more fragile material than either silver or gold, that its very worthlessness, despite its fragility, gives to it length of years.

We have said that clay is easily formed into vessels of almost any required shape. This is so within certain limits. Throughout these chapters I have lost no opportunity of insisting upon the importance of working any material in a befitting manner, and in the most simple and easy manner in which the material can be wrought. Almost every material can be simply "worked" in some way, or while in some particular condition.

Glass has a molten state, in which it can be "blown" into the most beautiful of shapes, and this process of blowing is the work of but a few seconds. Glass has also a solid condition, yet as it can be formed into works of great beauty by the exercise of momentary skill, it would be extremely foolish to take a mass of the solid glass, and by laborious grinding form it into a bottle or a bowl. It fortunately happens that if a material is worked in its most befitting manner, the results obtained are more beautiful and satisfying than those which are arrived at by any roundabout method of production. Glass should be formed into hollow vessels only when in its plastic condition, for it cannot be shaped into the form of such vessels as we require when in its solid state without the expenditure of much unnecessary, therefore wasteful, labour. But if a mass of crystal or marble must assume the form of a bowl or font, then the laborious process of grinding must be resorted to, for these substances have no plastic state.

The potter's wheel has been known from the earliest historic time, and this has at all times been the instrument with which the best earthen vessels have been formed. A mass of clay of suitable size is placed on a horizontal disc of wood, to which a rotary motion is imparted. The operator presses his thumbs into the centre of the clay, and then by causing his fingers to approach his thumbs, manipulates the clay into a cup, a bowl, a vase, an earthen bottle, or whatever form he may please; and if skilful, the operator can form objects of marvellous beauty with a rapidity that astonishes all who see his mode of working for the first time.

If potters would but content themselves, in order to the production of such articles as we require in common life, with the "potter's wheel," we should be almost sure of a certain amount of beauty in domestic earthenware, but such is not the case. They make fancy moulds of plaster of Paris and of wire gauze, and roll out clay as the pastrycook does dough, and manipulate it as so much pie-crust, instead of applying to it simple skill. Neither a bowl nor a plate need have a scalloped edge, indeed they are much better without it; and if unnecessary, and even undesirable, absurdities were avoided, and a simple and natural method of working each material alone employed, a great improvement in art would speedily take place.

It is strange but true, that the worker in one material seems rarely to be satisfied with making his works look as well and as consistent as possible; he desires rather to form poor imitations of something else. We have all seen earthen jugs made in imitation of wicker-work, although to do so is obviously foolish, as no wicker vessel could hold water, and the thing imitated is much less beautiful than a thousand forms which clay is capable of assuming. Men's heads without brains are, or were at least, favourite jugs. Well, there are many models for this idea in Nature I doubt not; yet why we should copy them by making a jug in the form of a hollow head, I know not. I have in my possession a milk-jug, such as is common in the district of Swansea in South Wales, in the likeness of a cow. The tail is twisted into a handle; by a hole in the back the milk is admitted, and through the mouth it is ejected. A more wretched and coarse idea it is scarcely possible to conceive of, yet many admire my jug. Let us work the material in a simple and befitting manner, and satisfactory results are almost sure to accrue. I have said that clay, as such, has many beautiful colours. Naturally clay is black, grey-white, red, brown, and yellow, and it is capable of assuming many desirable tints by the agency of chemical means. We do not use coloured clays as much as we should do. We want so much white—everything to look so clean. All ornamental ware, at least, should be artistic, and the art-effect should supersede that cold whiteness which the Dutch and the English mistake for cleanliness. A clay of good natural colour is not a thing to be hidden nor ashamed of.

Clay is capable, when glazed, of receiving any amount of colour, and of preserving these colours in their beauty for almost any length of time. These qualities are invaluable to the ornamentist. Colour is not always at his disposal. The goldsmith has difficulty in getting it, but to the potter it is very accessible. Colour is capable of giving to objects a charm which they could not possibly have without it. Let us use the power thus placed at our disposal rightly and well, and then the enduring character of the colour-harmonies which we produce may gladden our posterity in ages yet to come.

Clay is susceptible of the highest art-finish, or of a bold sketchy treatment. Finish is very desirable in some cases. The cup which my lady uses in her boudoir should be delicate and fine, for what is worthy to approach the sacred female lips of the occupant of a fair apartment but such a work as is tender and refined?

As a rule, however, we over-estimate the value of finish, and undervalue bold art-effects. Excessive finish often (but by no

means always) destroys art-effect. I have before me some specimens of Japanese earthenware, which are formed of a coarse dark-brown clay, and are to a great extent without that finish which most Europeans appear so much to value, yet these are artistic and beautiful. In the case of cheap goods we spend time in getting smoothness of surface, while the Japanese devote it to the production of an art-effect. We get finish without art, they prefer art without finish.

We shall have to consider "form" in the next chapter, and in this I intend to introduce a series of shapes of vases, such as we shall have to carefully study.

OPTICAL INSTRUMENTS.—XIII.

BY SAMUEL HIGHLEY, F.G.S., ETC.

ARTIFICIAL SOURCES OF LIGHT (*continued*).

The Electric Arc Regulator embraces such arrangements as control the combustion of the terminal poles of a voltaic battery, or a magneto-electric induction machine of sufficient power to produce the well-known "voltaic arc" shown in Fig. 38. The ordinary electric regulator provides for bringing a pair of carbon points in contact, and then separating them to a distance proportionate to the electric battery power employed, so as to produce what is called the electric or voltaic "arc"—that is, an electric flame carrying incandescent and vaporised particles from one pole to the other; and whenever the striking distance between the two poles becomes too great, it automatically brings them nearer, or "makes up," as we say; or if this distance has been overstepped by the breaking off of a piece of the carbon poles, etc., then it brings them in contact again, and repeats the operation so as to produce and keep up a constant point of light. On the precision of this action depends the value of the regulator. Usually fifty elements arranged for "intensity" are employed — seldom less than twenty battery cells, though twelve will give a small arc.

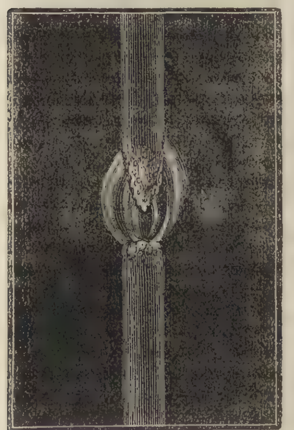


Fig. 38.

The battery usually employed is either of Grove's or Bunsen's constructions, of which Fig. 39 represents a single element of the latter arrangement; C is a rod of carbon, V a porous cell, Z a cylinder of amalgamated zinc, F a glazed pot, and P shows the component parts arranged for use.

The carbon is placed in the porous cell, outside this the zinc, and all these within the glazed pot. The porous cell is filled with strong nitric acid, and the glazed pot with dilute sulphuric acid. When arranged in battery the carbon of each element is connected with the zinc of the next, and so on alternately, as shown in Fig. 40, so that one end of the series ends in a carbon, the other in a zinc plate, or, as they are called, positive + and negative − terminals. In a Grove's battery the parts are similar, the carbon rod being replaced by platinum foil; but pots, zinc, and porous cell are made flat instead of cylindrical, as shown in Fig. 41, and so occupy less space. As Bunsen's battery is cheaper, and does not give off nitrous acid fumes so quickly as Grove's, through taking longer to heat, it is in very general use, especially on the Continent. From the trouble attending the fitting up and charging a number of battery cells which give off fumes that are irritating to the lungs, the electric light is seldom employed except at institutions, where an attendant is accustomed to the drudgery of this unpleasant operation; but we may hope that, before long, such drawbacks to its use may be obviated by improvements on the magneto-electric induction machines of Holmes, Wilde, Siemens, Wheatstone, or Ladd, which at present involve the use of a steam-engine to secure the required voltaic power, and hence can only be employed in fixed positions, as at lighthouses, institutions, and factories.

Notwithstanding the existing drawbacks to its general employment, the electric is *the* light of all others for optical experiments, the lantern microscope, photographic enlargements, and lighthouse purposes—in fact, whenever a *steady point of light of the greatest intensity* is a *sine quâ non.*

Highley's Hand Regulator.—In optical demonstrations a constant light is not a necessity, and as in many spectrum experiments it is often necessary to pull out the arc (by separating the poles to the verge of the "striking distance") to obtain the best results, it is desirable to have the apparatus completely under control of the operator's eye and hand; hence a regulator adjustable by hand may in such cases be preferable to a self-acting arrangement which, though keeping a constant and steady point of light, has not a brain to follow the exigencies of a delicate experiment.

The arrangement shown in Fig. 42 is simple, efficient, and cheap, and has the advantage of not readily getting out of order. An upright support, U, is attached to a mahogany base-board, B, and terminates in a tube fitting T, through which slides a rod, R, that carries the upper carbon pole. The lower carbon is supported by a tube, S, that fits easily over a solid inner support. All these parts are of brass, the upright U being strengthened by a turned wood casing. A long brass lever-arm, L, working on a wooden fulcrum, F, is raised or depressed by the action of a rack and pinion, P, with which it is connected by a slotted stirrup, working over two pins projecting from the opposite sides of the racked tube. The other end of this lever supports the sliding tube S, by a similar slotted stirrup working over two pins inserted in the opposite sides of S. A cord, connected with the lever-arm by two adjustable rings, A A, passes over a grooved wheel, W, and supports the upper pole R. The upper and lower poles are connected by wires with their respective binding-screws, as shown in Fig. 41. On raising the racked end of the lever, both poles are separated to their utmost to allow of the carbons being inserted in their supports. On connecting the arrangement with a source of voltaic power, the carbon points are brought into contact by depressing the racked end of the lever-arm, and when well ignited, they are separated to the proper distance by reversing the action of the pinion. By a suitable adjustment of the sliding-rings, A A, the cord can be brought nearer to or further from the fulcrum F, so that the poles may be made to approach each other in the ordinary ratio for the combustion of carbon of 2 to 1, or in other ratios when various bodies are burnt for spectrum experiments. It will be seen that this arrangement is well suited to meet the requirements of spectrum demonstrations, and by careful manipulation, while watching the arc through a coloured glass, a steady light may be maintained during the ordinary period of a lecture-room experiment. As I have stated this hand regulator is well suited for spectrum demonstrations, I will here describe a convenient arrangement for carrying a number of carbon crucibles charged with metals or salts, an accessory which saves the lecturer's time and the patience of his audience. To a piece of tube, *t*, of the diameter of an ordinary carbon, is brazed a projecting arm, *a*, to which is attached by a pivot a disc of metal, *d*, that carries on its upper surface a number of slotted tubes, *c*, a size larger in diameter than the brass rings with which the carbon crucibles are shanked; into these the crucibles are fitted. By such arrangement, it will be seen that on fitting *t* into the carbon support, S, any crucible-holder of the series can in turn, by a partial revolution of the disc, be brought beneath the upper carbon of the regulator, and the characteristic light of its contents evolved, without wasting time by the usual method of removing and replacing a crucible for each experiment.

A section of a carbon "spectrum crucible" is shown at C; its upper part is thick and eight-sided; its lower end is turned, and shanked with brass tube, of *a gauged size*, so that all the carbon crucibles (and points also) may just drop into the holders of the regulator, and when clamped by the binding-screws, not only ensure good metallic contact, but also the perpendicularity of crucibles or points.

Carbon points of English make are usually round; foreign carbons are more frequently square and of various sizes. A convenient arrangement is shown at P for adapting such carbons to a regulator. It will be seen at a glance that by the action of a screw, *s*, worked by a square key, K, the two rectangular jaws of a clamp, C C, may be expanded or contracted to grasp a square carbon, whether it be large or small. This clamp is fitted to the regulator by a tube *t*, of the gauged size for round points;

and I may here say it would be a great advantage if philosophical instrument-makers would adopt some universally recognised size for the carbon-holders, in the same way as the Royal Microscopical Society has established gauges for the screws of object-glasses, glass slides, etc. A convenient size for these brass shank tubes is $\frac{3}{8}$-inch diameter by $\frac{1}{2}$-inch long, consequently the receptacles in the regulator should be just a shade larger in diameter.

The Electric Regulators of Duboscq, Serrin, and Holmes.—The regulators in general use on the Continent are those of adjusted to, for as long a period as the source of electric power remains constant, but is also the simplest and cheapest I am acquainted with. In this arrangement the lower end of the curved rod, R (Fig. 45), that carries the upper carbon, is weighted, and rests on an air-ball, A, placed in a cylinder; an exit-pipe from the air-ball is closed by a stopcock, C, which can be opened or shut by the action of an iron core fitting into a hollow electro-magnet, M, placed in the circuit, and suspended on the end of a lever-arm, L, that is fixed to the plug of the stopcock C, a counterpoise spring, S, being attached to the other

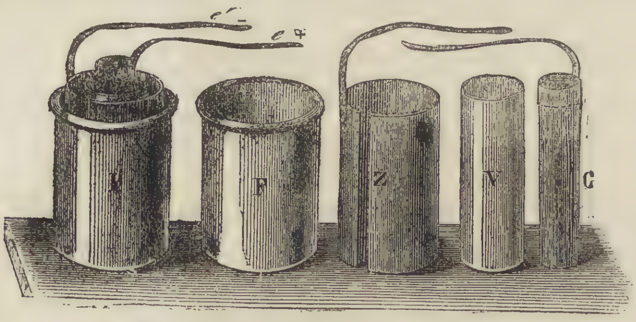


Fig. 39.

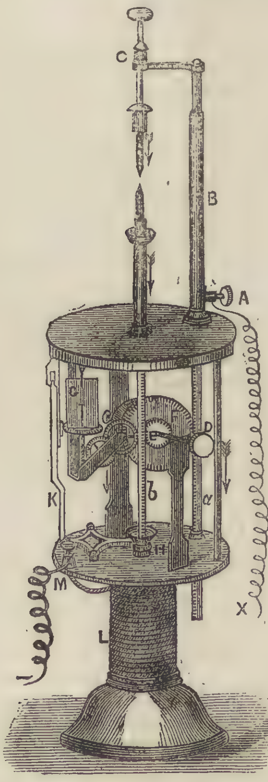


Fig. 43.

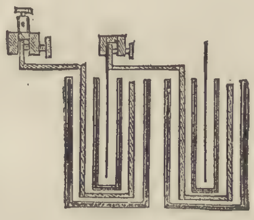


Fig 41.

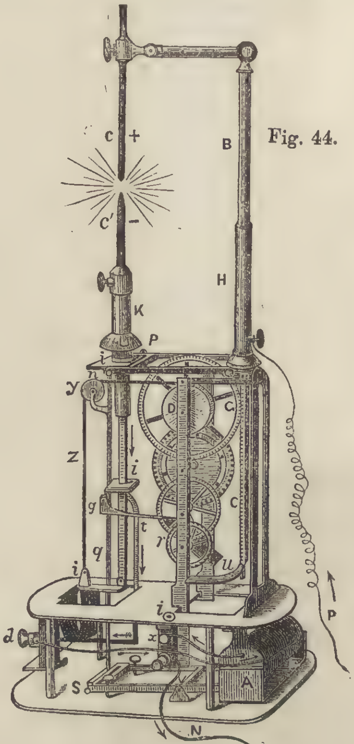


Fig. 44.

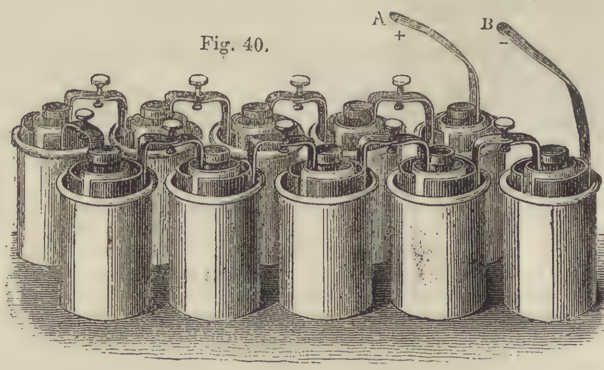
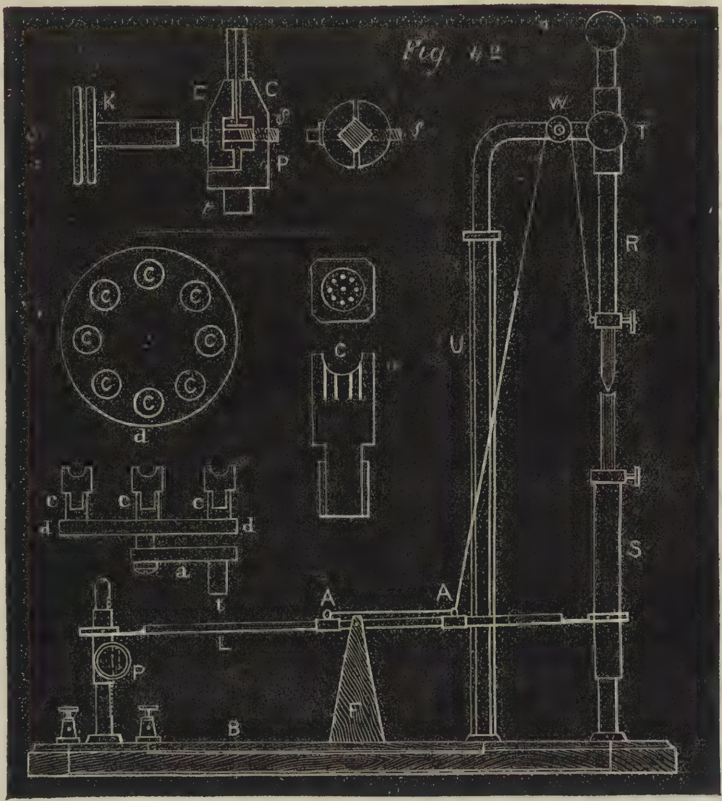


Fig. 40.

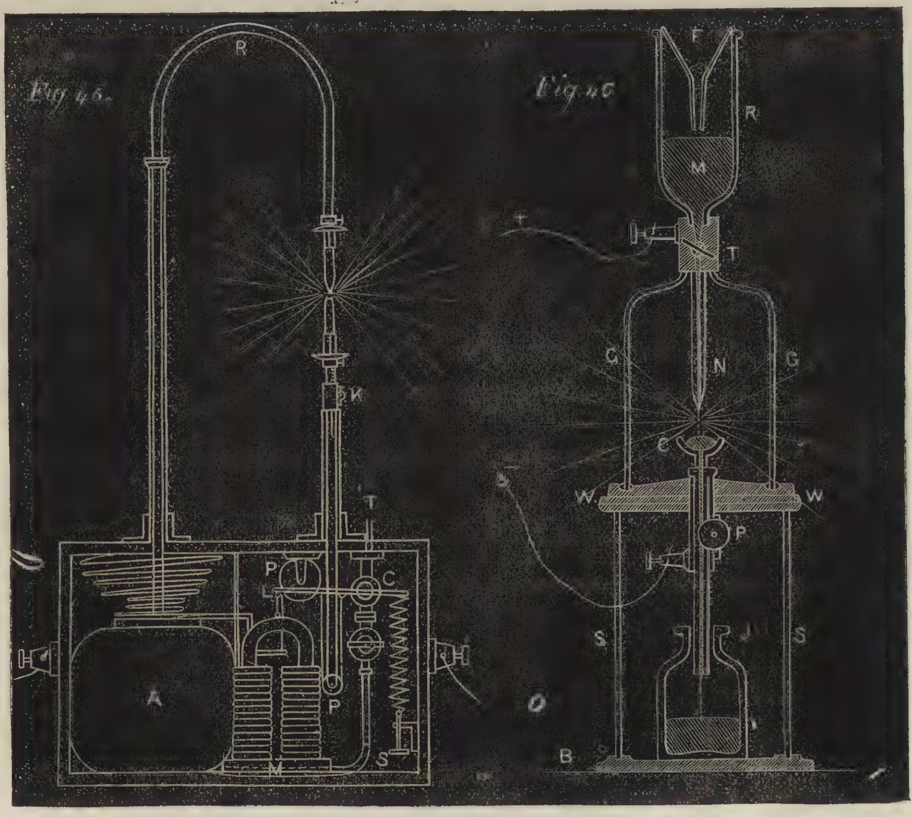
Duboscq and Serrin; they have also been employed at the Royal and other Institutions in this country, and are represented in Figs. 43 and 44. It will be seen that a train of cog-wheels enters into the construction of both these arrangements; the same holds good with regard to the very beautiful instrument of Holmes, designed more especially for lighthouse purposes. As Duboscq and Serrin's instruments have been described at pages 264, 265, Vol. V., of THE POPULAR EDUCATOR, I need not occupy space here, but will select as the typical representative of an automatic regulator, an arrangement in which the complication of a train of cog-wheels is dispensed with, the action being made as direct as possible.

Malden's Pneumatic Regulator, the invention of one of our most expert public lantern exhibitors, is not only the most sympathetic self-adjusting electric regulator, giving a constant and steady point of light, central with any optical arrangement it is end of the lever arm, to adjust the action according to the amount of battery power employed. On the air-ball being filled by means of little bellows, fitted to the tube T, the two poles of the regulator are separated. The carbon points are then inserted, and on connection being made with the source of electricity, the poles are allowed to fall together, the stopcock being kept open for the purpose of allowing air to escape from the compressed ball. As soon as the carbon points touch, a voltaic circuit is established, the iron core or horse-shoe armature is pulled down by attraction into the hollow electro-magnetic helix M, and the stopcock C is closed, but the poles at once separate to the striking distance of the battery power employed, and, as they burn away, the stopcock is slightly opened, so that a small quantity of air escapes, and thus allows the air-ball to collapse, and consequently the upper carbon gradually to descend, while, by



a pulley arrangement, P P, connected with the falling weight attached to the upper carbon support, the lower carbon is simultaneously raised in the required ratio of the combustion of the upper to the lower carbon—viz., 2 to 1, or more accurately 22 to 10—thus securing centrality with the optical apparatus employed. Should a portion of carbon break off, the striking distance being overstepped, the current is broken, and the stopcock is again opened, when through the escape of air from the ball the poles are rapidly brought into contact, again to start apart in automatic adjustment. By a rack-and-pinion adjustment in the lower pole K, the point of light can be accurately "centred" with any optical arrangement. During spectrum experiments the bellows are kept connected with the air-tube T, and by pressing air into the air-ball A, the poles can be separated with the greatest delicacy of manipulation, and the arc drawn out to the verge of the striking distance. This arrangement is also suited for lighthouse purposes, as from its extreme simplicity of construction it can be easily kept in working order or repair by a man of ordinary intelligence, and this cannot be said of the complicated regulators usually employed. The writer of the article in THE POPULAR EDUCATOR, previously referred to, says (page 266), "After working with many different varieties of lamp, we have no hesitation in pronouncing this the most manageable and generally useful one we have yet seen;" but, with a curious want of patriotism and *esprit de corps*, omits to mention that it is the invention of a fellow-countryman and lecturer, though very properly he does *not* omit to affix the names of Duboscq and Serrin to the instruments of French manufacture.

Way's Mercurial Light.—This is the simplest of all the contrivances for producing an intense light by voltaic power, but has the serious drawback of emitting rays of a most ghastly tint, which are monochromatic and characteristic of incandescent mercury. As with the monochromatic sodium light, the human face appears cadaverous, but more intensely so, and the bluish-violet hue reminds one of the final stage of animal decomposition; but on the other hand, the colours pertaining to the violet end of the spectrum, such as mauve, appear of extraordinary brilliancy. As might be deduced from this fact, the mercurial light is rich in actinic rays, and so well adapted for photographic purposes; and to such applications, and lighthouse illuminations, its use is at present restricted. In this arrangement the usual carbon points are replaced by a fine stream of the liquid metal mercury, which flows from a reservoir through a very fine iron nozzle, into a little iron funnel that allows the mercury to flow away at the same rate as that at which it descends from the reservoir.



For a certain distance the mercury descends in a solid column, and then breaks up into little beads; the light emanates from this point of disruption, and the nearer this occurs to the jet, the brighter are the rays emitted.

A simple arrangement of Professor Way's light is shown in Fig. 46. The mercury, M, is placed in a glass reservoir, R, to the lower end of which is an iron cap fitted with a tap, T, of the same metal (iron not being attackable by mercury), that controls the flow to an iron nozzle pierced with a very fine bore, N. The reservoir and its appurtenances is fitted by an iron cap to the top of a cylindrical glass shade, G G, the lower margin of which drops into a gutter turned in a wooden stand, W W. Immediately beneath the point of the nozzle an iron cup-shaped funnel, C, is fitted into the stand, W, by a tubular fitting, and is adjustable by a rack-and-pinion motion, P; beneath the aperture of this funnel is placed a jar, J, to receive the mercury as it passes through the arrangement. The stand, W W, is sustained by four iron supports, S S, fixed to a mahogany base-board, B. Binding-screws, + and −, are fixed to the reservoir R, and the fittings connected with the funnel C for making connection with the respective terminals of the battery. On the jar J being filled with the contents of R, the mercury is poured back into the upper reservoir through a vulcanite funnel F, into which a plug of cotton wool is placed to filter the mercury from dirt and oxidation, so that this light may be kept in action for an indefinite period. On this apparatus being first brought into action, the mercury condenses on the cold glass shade, and running down into the circular gutter soon forms a liquid air-tight joint, from which the mercurial vapour cannot escape. The deposition of the mercurial vapour greatly impedes the amount of light given off, but the heat of the incandescent metal being very considerable, the glass, after attaining a certain temperature, remains free from deposit. As the fumes of mercury are well known to be noxious and producing salivation, this apparatus has been objected to as dangerous to those employing it; but the same may be said of a gun, steam-engine, and many other useful contrivances, and with truth, if we do not follow the precautions that experience and common sense indicate. The point of light in the mercurial regulator is of apparently greater magnitude than that given off from carbon points, even when only thirty of Grove's elements are employed, the number found by experience to give the best effect with this arrangement. It is said that Way's light cannot be worked by the magneto-electric machines recently employed in place of the voltaic battery, a point that requires investigation.

BRICK AND TILE MAKING.—IV.

BY GILBERT R. REDGRAVE.

TERRA-COTTA, BRICKS AND TILES.

As we stated in our last article, the clay employed in brick-making by the semi-dry process requires but little selection or preliminary manipulation, owing to the finely-divided state in which it has to be used. All the lumps and impurities, in fact, are ground up small, and incorporated so thoroughly throughout the mass, that their presence can scarcely be detected. In preparing the clay, on the other hand, for manufacture in the plastic state, the removal of the impurities is of the first importance, and it is mainly owing to the very imperfect way in which this is generally accomplished that many of our English bricks are so unsightly and defective. It is easy enough to point out theoretically the best way of producing a pure and well-tempered material, but the difficulty in practice is to do so at the almost nominal price which can be set apart for this process of the manufacture.

As we saw in the case of the terra-cotta, the clay is first hand-picked, then ground to a fine powder, and finally pugged with hot water in order to temper it. For pottery, again, the clay is what is termed "blunged"—that is, it is beaten up in tanks of water by means of powerful revolving arms or cutters. In this way the lighter and purer portions of the clay are brought to a sort of creamy consistency, and are carried away in the overflow water; while the heavy and more solid impurities, which consist generally of iron or limestone, sink to the bottom, and may be from time to time withdrawn. In this process, which differs but slightly from the action of the common wash-mill, the clay is admirably tempered, but remains in far too liquid a state for use. It has consequently either to be run into tanks or reservoirs, in which the water may be gradually evaporated by the natural action of the atmosphere, or the water must be driven off by means of artificial heat, as is done in the so-called "slip-kilns" in the potteries, where the liquid clay is conducted into shallow pans about eight inches deep, having flues beneath them in which the heat and flame from a furnace at the one end passes into a chimney situated at the other, thus causing the clay-slip to boil, and in about twenty hours to be ready for use. By either of these methods the clay can be admirably and efficiently prepared, but they are far too costly to admit of their application in the case of clay used for common bricks. We should estimate the dry method to cost 1s. 3d. per ton, and the washing and boiling little short of 2s. per ton, whereas from 4d. to 5d. per ton is all that can fairly be set down for this stage of the manufacture.

Unless the clay is by some method thoroughly disintegrated, the brick is nearly certain to appear streaky in fracture, as in every clay-pit there is sure to be a number of different beds or layers, which burn to a slightly different tint, and unless these are completely intermingled, the exterior of the brick is often spotty or mottled. The plan we spoke of in our last article as most commonly adopted for dealing with the clay—namely, horizontal rollers placed one above the other, and set to varying degrees of fineness—is, when taken in conjunction with a good pug-mill, perhaps the next best mode of dealing with the clay. The chief disadvantages of this system are, that if impure limestone or "skerry" is present in considerable quantities, it is not broken up sufficiently small to prevent the swelling or disruption of the finished bricks when exposed to moisture; for, contrary to the common opinion that the damage to such bricks is due to the winter frosts, we believe that their destruction is caused by the slaking of the lime in them. It is evident that, in the firing, the carbonic acid in the limestone is driven off, and there thus remain numerous nodules of quicklime: as the damp gradually penetrates into the bricks, the lime slakes and expands with sufficient violence to break it up, and occasionally even to upheave vast masses of walling. Thus it is not uncommon, in districts where these limey bricks abound, to find lofty walls and chimney shafts most singularly distorted. We have seen a tall chimney warped as much as a couple of feet out of the upright, owing to the expansion of the bricks on the south-west side, being that which was exposed most often to the driving rain.

Another common impurity in clay, nodules of ironstone, or argillaceous iron ore, is so hard and tough that the rollers seem to have but little effect upon it, and when it is present in the finished brick it causes extensive flaws and discolourations. Lastly, the rollers themselves are anything but good mixers, and their action in this respect is not so well supplemented as it should be by the pug-mill, which consists, as our readers will remember, of a pan or cylinder, in which revolves a central shaft furnished with knives, or cutting-arms, attached to the shaft screw fashion. The clay is inserted at the top of the pan, and is gradually forced downwards, and cut through and through by the knives, until it issues at length through an orifice at or near the bottom. The danger is that during its progress, partly owing to its being too dry or tough, and partly to the way in which the cutters are placed, the clay is apt to get pressed into a sort of worm, which, instead of being properly worked and tempered, merely gets turned round and round, and finally comes out very little better mixed than it was when it went in.

In the old-fashioned hand-tempered clay, the mixing was in reality far better accomplished than at present, for not only was the material well kneaded and trodden by the barefooted workman, but it was often "wedged" and cut up into small pieces, which were properly amalgamated by being beaten up and thrown back with great violence on to the remaining portions of clay. It is the slapping and kneading action, in short, which we look for in vain in modern clay-tempering machines, and until something in this way is effected we shall never get truly tough common bricks.

Having thus shown what is required by way of preparation, we may say a few words on the composition of the raw clay, and show the manner in which certain materials influence the ultimate strength and qualities of the brick. We have noticed the effect of the more common impurities, lime and iron, when present in the shape of lumps or nodules, and we may now

explain the action of these substances upon the silica and alumina, which are the chief constituents of the clay. Pure silicate of alumina, as we have shown, is infusible, but very small quantities of lime, iron, or the alkalies act as fluxes, and at high temperatures run the mixture into glass. It has been found, however, that under certain conditions, and mixed in certain proportions, these materials will bear great heat without fusing, and Dr. Ure asserts that a mixture of equal quantities of lime and alumina, with one-half part of silica, gives a refractory compound, and that this result is also obtained if the amount of lime is increased one-half. We know, in fact, from the so-called gault bricks, that an intimate mixture of chalk and clay will burn very hard. The gault clay, which underlies the chalk, may contain often as much as 30 per cent. of carbonate of lime, and when made into bricks it burns of a yellow or whitish colour, and, owing to undergoing a partial fusion, becomes very hard, but at times rather brittle. The Suffolk white bricks, on the other hand, which also owe their colour to the presence of chalk in the clay, in consequence of the large quantity of sand they contain, will not burn so hard as those made from the gault, and are so friable that they may be readily rubbed and cut into any required form. Again, the Staffordshire blue bricks, which are made from a clay containing as much as 10 per cent. of peroxide of iron, will stand only a moderate amount of heat, and produce, according to the way in which the firing process is conducted, either a red, a buff, or a blue brick. If the clay used for these bricks is subjected to the full heat of a terra-cotta kiln, it is entirely melted and run into a dark glassy slag: it not unfrequently happens, in fact, that some of the lighter goods in the top of the blue ovens get partially melted in endeavouring to finish the more bulky articles at the bottom.

The natural clay, as it comes from the pit, is rarely used for brick-making without some admixture either with other beds or with sand, and the goodness of the brick depends mainly upon how far this is done judiciously and skilfully. Most pure clays are too tough to use as they are dug; they would not leave the moulds properly, and would shrink and twist so much in firing as to be valueless; they are therefore mixed either with sand alone, or beds of sandy loam are selected and worked up along with the other clay in certain fixed proportions. Another very important point in preparing the clay is the amount of water it will bear, or the quantity of natural moisture it contains; the consistency of the clay makes all the difference in moulding, and the difference in the shrinkage of the same clay with varying quantities of water is very remarkable. As it is of great importance that the bricks should all be uniform in size, it follows that the clay should all be prepared alike, and have the same quantity of water in it. For this reason it is customary to mix up large quantities of brick-earth at a time, and in making any mixture of earths it is found convenient to spread the different beds in thin layers one over the other in large shallow heaps. In using this clay, it is dug down from top to bottom as it is required, and thus a uniform distribution of each of the component layers is ensured and an equable result is obtained.

We have already briefly alluded to the kind of press which is generally used for the manufacture of bricks from plastic clay, and it will readily be understood that, with certain slight mechanical differences, the machinery for this purpose consists in the main of a receptacle for containing the prepared clay, a means of forming this clay into a stream of suitable size and form, and a contrivance for cutting up this stream or strip of clay into individual bricks. In some cases the plastic clay is forced into moulds, and made much in the same way as bricks made by hand, and this mode of proceeding has the advantage of producing a brick of better shape and exterior than one made without moulding. The difficulty of the pug-mill process is that the stream in issuing from the orifice of the cylinder is (especially if the clay is a little too dry) liable to become cracked and jagged, and this cannot, of course, be remedied unless the bricks are dressed or gone over before they are quite hard to remove the unevennesses. Again, the wire cutters get clogged with a little dry clay, and fail to make a clean cut, thus causing the bricks to look as if they had been sawn apart. To remedy the former evil, in some machines the orifice of the pug-mill is formed by four friction rollers, which are constantly lubricated, and thus produce an even and smooth band of clay. The bricks are carried from the machine either by children, by hand, or they are wheeled away on barrows specially made for the purpose, which consist of a large platform of thin battens of wood, with a single wheel, somewhat in the form of a costermonger's barrow. It is almost impossible to give any general statement of the plan of drying machine-made bricks, as the practice varies so much in different parts of the country. It may be roughly stated that, owing to the tougher and dryer state of the clay, as used for machine-moulding, the bricks can usually be built up into open walls or "hacks" at once, instead of being first spread out singly on the ground or on drying-floors to harden; but this does not, of course, hold good with all kinds of clay. It is as a general rule more economical to use the clay in such a state as to be able to hack the bricks at once, as this effects a great saving of room, and saves handling them twice. The common plan of building up the bricks is to place them on edge, in double diagonal rows, about two inches apart, each course crossing one another at right angles; the hacks may be from ten to fourteen rows high, and it depends upon the time of year and the state of the weather how long the bricks have to remain before being placed in the kiln. We should think a fair average time was ten days or a fortnight.

Bricks are burnt either in uncovered heaps, called "clamps," or in kilns similar to those we have described for terra-cotta. Clamp-burning is, in reality, a rude and barbarous plan of avoiding the necessity of constructing kilns, and this system not only occasions great loss and waste in the fuel and in the bricks, but it entails certain differences in the preparation of the clay, which cannot fail to injure the bricks made to be burnt in this way. We do not propose to speak of clamp-burnt bricks at any great length, but we may state briefly that the clay for this purpose is mixed with certain proportions of coke-dust, sifted cinders or breeze, and therefore contains within itself a part of the fuel required to burn it into bricks. It is evident, therefore, that in the firing, the particles of coke or cinder burn away, leaving very unsightly and injurious cavities in the bricks. The clamp is a vast heap of unburnt bricks, built upon a foundation of those previously burnt, with intermixed layers of coke-dust, and protected or encased on the exterior with walls of semi-burnt bricks called "burnovers." The fuel, which is generally breeze, is distributed in thin horizontal layers through the clamp, and the bricks are built up with interstices to admit of the fire penetrating through the mass. The clamp is lighted by means of a number of receptacles for fuel contrived in the outer walls, called "liveholes," and when once lighted a clamp may burn, according to the quantity of fuel in it and the dryness of the brick, for from three to six weeks.

The vast number of bricks wanted in and round London, and the facility afforded to the brickmakers of disposing of any quantity of rubbishing articles, has rendered clamp-burning almost universal in the London district, and we think that the badness of most of our London bricks may be traced to this pernicious system of firing. We trust that, before long, clamps will no longer be permitted in the vicinity of our dwellings, for, owing to the want of air in the interior and the badness of the fuel, the gases given off from them are very deleterious to health. This plan of burning is also most wasteful, as a large proportion of the bricks are always underburnt, while those at the bottom and near the "liveholes" are run into clinkers; the brickmaker can, in fact, exercise little or no control over his work, and when once fairly started the clamp burns away as it will. Mr. Dobson, in his treatise on bricks, gives a very careful account of the mode practised round London of preparing and burning the clamps, and the method he describes prevails, with very slight differences, in many parts of Surrey and Kent.

The purposes for which a brick is required should be carefully studied in its manufacture; thus the same clay, with slightly varying proportions of sand or chalk, or with a slight difference in the firing, may produce a vitrified brick, incapable of being rubbed or cut, or it may be made into a soft rubber, which can readily be cut into any desired shape. Again, as we have already stated, certain clays may be burnt either red, buff, or blue, and knowing the capabilities of his material, the manufacturer frequently has it in his power to prepare a great variety of useful articles from brick-earth. We have often been astonished to find the vast amount of ignorance which prevails upon the reasons for certain well-known processes in brickmaking, and we have therefore dwelt at considerable length upon those details which are involved in the preparation and treatment of the clay.

OBJECT DRAWING.—X.

THE group shown in Fig. 59 consists of eight blocks of wood stacked at right angles to each other.

It will be clear that the blocks thus placed would form a group which could be contained in a cube; and, therefore, having determined the position of the nearest angle, proceed to draw lines to vanishing-points, which will be fixed according to the inclination of the sides of the object in relation to the picture-plane. The points *b* and *c* are next to be marked, and these two will be determined in the same manner.

Now from *b* and *c* draw lines to the opposite vanishing-points, and thus the ground-plan of the entire block will be perspectively rendered.

points will divide the whole containing block into four slabs lying horizontally.

From *h*, *i*, *j*, and *k* draw perpendiculars, which, cutting the lines drawn to the vanishing-points, will give the ends of the blocks *h i*, *m l*, *j k*, *o n*, and all others immediately above them in the same plane.

From the angles of these ends draw lines to the vanishing-points on the opposite side. The remaining lines will be readily seen from the drawing.

The shading is simple; the light proceeds from a point on the left of, and higher than the object, and thus the brightest light falls on the end of the block *i h l m* and those immediately above it, and on the left side of the blocks over the point *d*, the right side being, of course, in shadow. The cast shadows caused by

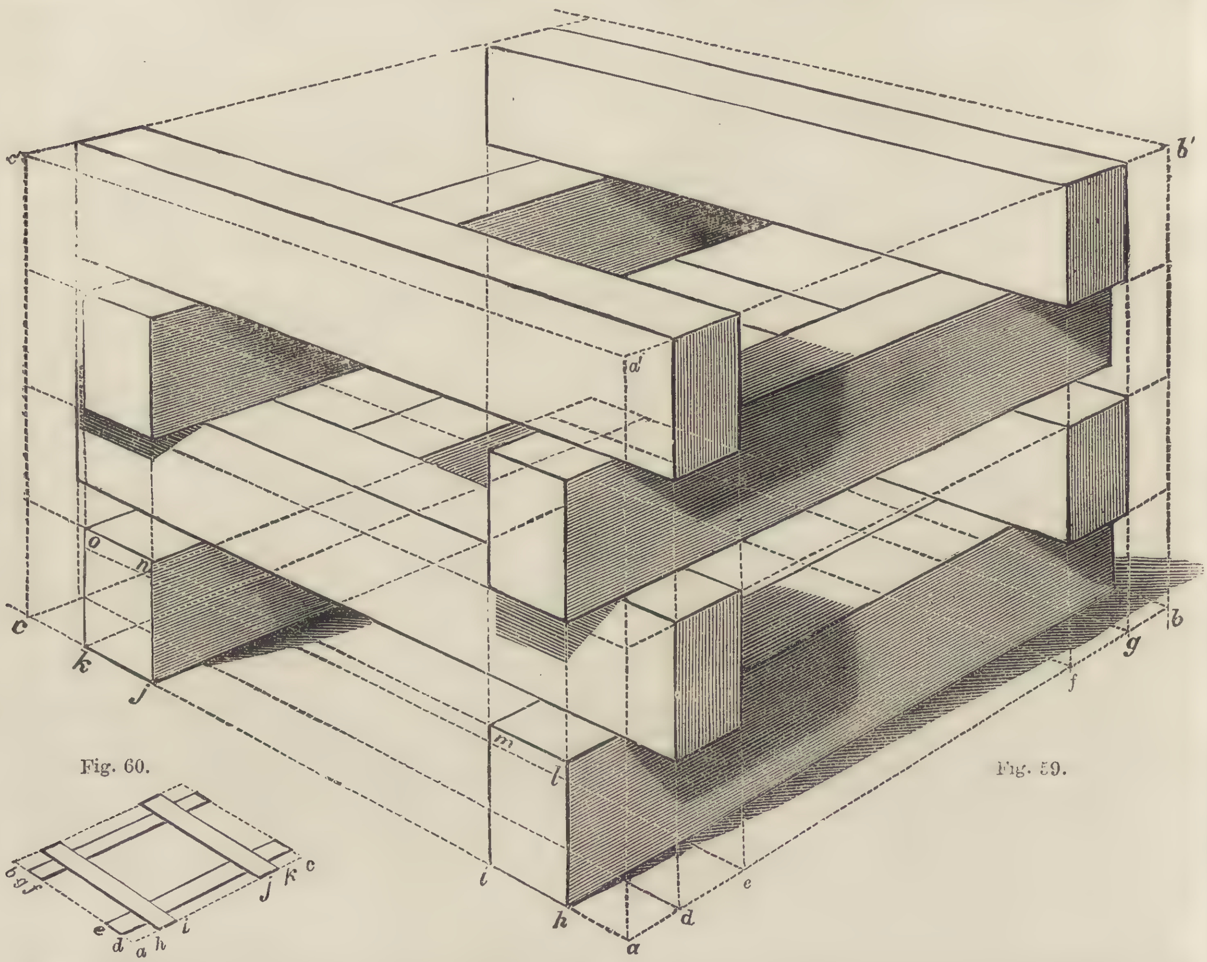


Fig. 59.

Fig. 60.

From *a* mark *a h*, representing the apparent distance of the lowest block from the immediate foreground, and also *a d* for the same purpose on the other side of *a*. From *b* set off *b g*, and from *c* set off *c k*, observing that these distances being removed from the foreground will be smaller than *a d* and *a h*, although representing the same space.

Again, from *d* set off *d e*, representing the thickness of the block, and also *h i*, *j k*, and *f g*, the last two distances being diminished for the reason already explained.

At this stage the student is referred to Fig. 60, which is a reduced copy of the ground-plan, and from this it will be seen that the ends of the blocks are portions of the planes which form the sides of the containing block; thus the lines *d e*, *f g*, *h i*, and *j k* are on the lines *a b* and *a c*.

Proceed, therefore, to sketch the perspective view of this plan as already shown.

Draw the perpendicular *a*, and set off upon it the heights of the blocks—viz., to *a′*; lines drawn from these to the vanishing-

the ends of the bars projecting beyond those immediately under them will best be studied from the objects, since they vary with every movement of the illuminating point, however slight that movement may be.

It cannot, in fact, be too frequently impressed upon the student that the illustrations in these lessons are not by any means intended as *drawing copies*; they are designed to serve as guides—in placing the models, and in the *method* of drawing. There is more to be learnt in one hour's study from the merest blocks of wood than from the most careful work from copies, though it may extend over weeks.

One of the most important features of object drawing is that a student who really wishes to *work* need never be stopped by the want of subjects. Every block of wood or stone, however simple its form—and the more simple the better—will afford ample lessons in form, and in light and shade.

As already mentioned, a special set of models has been designed to carry out the lessons given in this subject; but in

order to aid students who have not the opportunity of using these, it is easy to contrive a set of patterns by which any one of common intelligence may be enabled to make a set of models of cardboard, which, although not very permanent, will still be found very useful. In making these, however, the student will have to bring to bear a certain knowledge of practical geometry and projection. These subjects could not conveniently be included in the present lessons, and the student is therefore referred to those in which they are specially treated. This knowledge will not only be found useful in this particular study, but will be the foundation of all true notions of form.

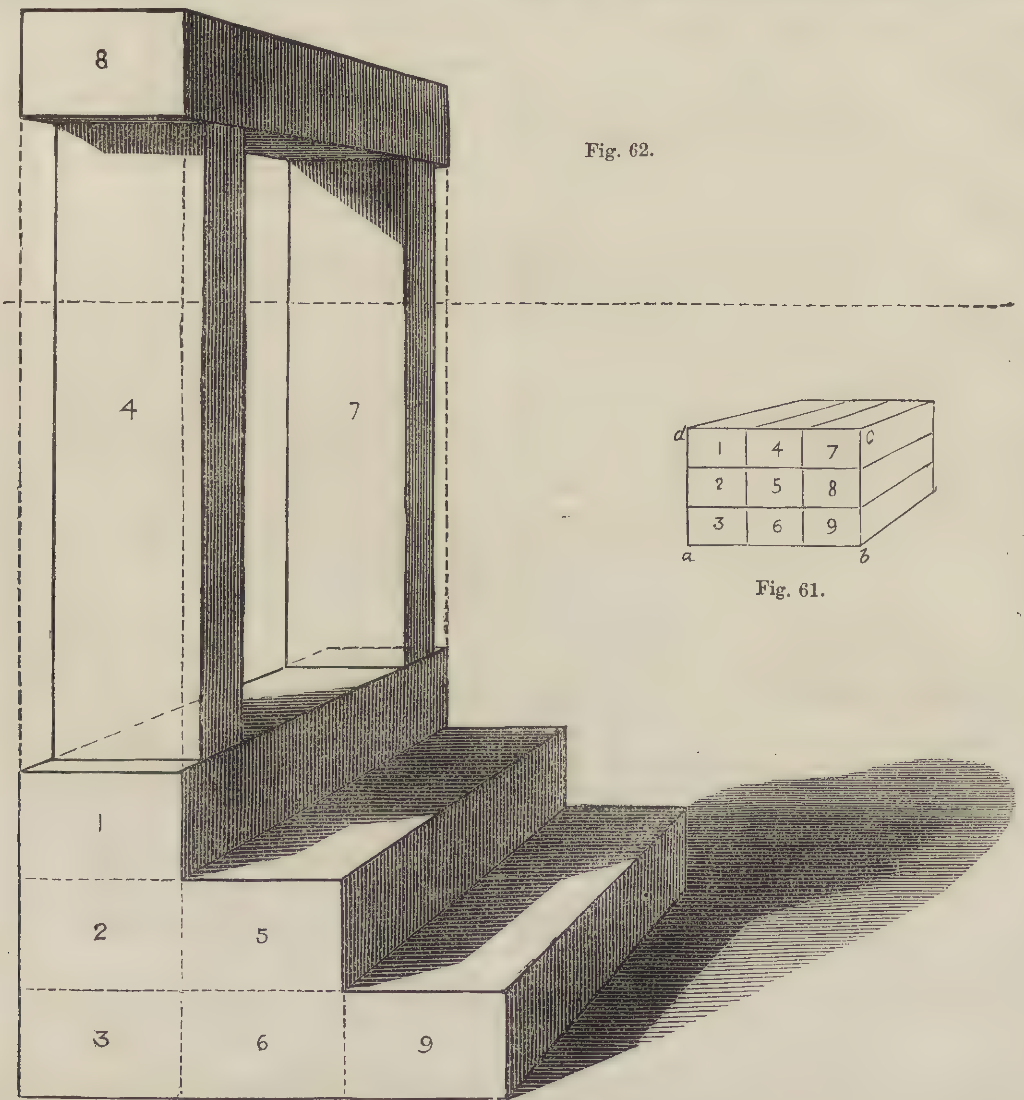


Fig. 62.

Fig. 61.

Fig. 61.—The group shown in this figure is made up of nine blocks similar to those used in the last figure. The end of the group being parallel to the plane of the picture, will be rendered geometrically—that is, of its correct form, since it is not altered by its position.

Having, then, drawn the rectangle *a b c d*, draw lines vertically and horizontally so as to divide it into the required nine rectangles. Observe that, in the object under consideration, the whole rectangle will be in the proportion of 6 to 9; since in the model each block is 3 inches wide and 2 inches high, the whole rectangle is thus one-third wider than its height. From *b*, *c*, and *d* draw lines to the point of sight, and complete the block by the distant vertical and horizontal lines. Then from the points where 1 and 4, 4 and 7, 7 and 8, 8 and 9 adjoin, draw lines to the point of sight, which will complete the view of the object.

Fig. 62.—This is an application of the foregoing figure. Thus it will be clear that, on removing the blocks 4, 7, and 8, the remainder, consisting of 1, 2, 3, 5, 6, 9, will form three steps.

Now from each angle draw a line to the point of sight, which will give the inner and outer angles of the steps—that is, the meeting of the risers and treads.

The lines representing the distant edge of the steps, which are required to complete this portion of the subject, require some care. It must be borne in mind that the risers of the steps are upright, and the treads horizontal, and that as their position is not altered by perspective, the ends of the steps being parallel to the picture-plane, the lines corresponding with these in the distant end must be vertical, and horizontal also. The special attention of the student is called to this point.

We now proceed to employ the blocks 4, 7, and 8, which had been removed from the original block, by placing two (4 and 7) as the posts or jambs, and 8 as the lintel.

The method of drawing this doorway has been given in previous lessons, and need not, therefore, be repeated here.

The whole of the front of the drawing, as well as the risers of the steps and the soffit, are in shade, and the cast shadows fall on each step—on the jamb and on the ground. These shades and shadows should, as already stated, be effected by means of lines drawn in the direction of the surface on which they fall.

AGRICULTURAL CHEMISTRY.—X.

BY CHARLES A. CAMERON, PH.D., M.D.,
Professor of Hygiene in the Royal College of Surgeons, Ireland, etc.

CHAPTER X.—SEWAGE MANURE.

A LARGE proportion of the food produced in these countries is consumed in the rural districts, and its elements restored to the atmosphere and soil of the localities in which it has been developed. If all the food produced in a certain locality were consumed on the spot, and its disorganised constituents wholly given back to the air and ground, then the soil of the place would always remain (if naturally fertile) in the highest state of productiveness—that is, it would continue in good condition. In the United Kingdom, fully one-half of the population reside in towns, and in these densely-crowded places at least one-half of the agricultural produce of the country is consumed. Now the amount of disorganised animal and vegetable matter conveyed from towns to the country districts is very small, and at present it may safely be stated that at least three-fourths of the amount of food conveyed into towns are, after being disorganised in the bodies of animals, carried off in the form of sewage into rivers and the ocean.

Two evils have resulted from the present system of discharging the waste matters produced in towns into rivers. Firstly, there is an enormous waste of valuable fertilising matters; secondly, many of the most important rivers are now little better than common open sewers. These evils have formed fertile subject-matter for books, pamphlets, essays, papers, editorial articles, indignant remonstrances, lectures, Parliamentary inquiries, and scientific commissioners during more than a quarter of a century past; and at the present time the remedies suggested and being applied for their removal or abatement involve the solution of one of the most important social problems of the age.

So enormous are the quantities of phosphates and alkalies stored up in the soils of these and other countries, that the most improvident system of agriculture cannot, as we have already shown, permanently deteriorate the land; and therefore, even should the present waste of town sewage continue, the gloomy prediction of Liebig, that the soils of Great Britain would at no distant date be reduced to sterility, is not likely to be realised. On the other hand, it is quite evident that the agriculturists of Great Britain have not at their disposal an adequate quantity of home-produced manure, otherwise they would not be obliged to import annually several millions worth of guano and similar fertilising agents from various and distant parts of the world. The quantity of food exported from these countries is quite trifling, whilst an immense amount of both animal and vegetable aliments is imported. It is clear, then, that were it not for the waste of town sewage the soils of Great Britain would, as a whole, obtain more phosphates and alkalies in the form of manure than is extracted from them in the shape of food. If the waste matters produced by the disorganisation of all the food of home and foreign origin consumed in these countries were applied to our soils, we should be spared the necessity of ransacking the most distant parts of the globe for guano, phosphates, and potash; whilst our soils would gradually be raised to the maximum condition of productiveness. We fear, however, that there will always be found insuperable mechanical difficulties in the way of transporting the waste matters of towns in such a way as to distribute them over wide areas. In most of the towns of the United Kingdom the water-closet system is very general, and the same main sewers which convey the drainage from the houses also carry off the rain-water. The liquid and solid excreta of the population constitute extremely valuable fertilisers; but when they are very largely mixed with water their agricultural value is very much lessened. Now the present water-closet and sewerage systems in towns has the effect of converting nearly all the manurial matters produced within the urban districts into a very dilute solution, containing a little solid matter in suspension. This liquid cannot economically be conveyed throughout the country in the same way that guano, lime, and stable manure are distributed. It is clear, then, that we should either prevent the manurial matters produced in towns from entering the sewers, or apply the sewage for the purpose of fertilising limited areas of land. Attempts to utilise town sewage have been made in various parts of England and Scotland, and on the whole not unsuccessfully; and at the present time the municipal authorities of several large towns are taking steps for the purpose of applying the sewage produced in their jurisdictions to agricultural purposes.

The composition of town sewage varies, and is influenced by the rain-fall, the quantity of pipe-water supplied to the town, and other factors. I have repeatedly analysed the sewage of Dublin, and the following appears to be its average composition.

COMPOSITION OF 100 TONS OF TOWN SEWAGE.

	Pounds.	Worth at per ton.		Money value.	
1. *In complete solution.*		£	s.	s.	d.
Nitrogen	16·50	70	0	10	3·75
Phosphoric acid	3·85	40	0	1	4·50
Salts of potash	5·12	20	0	0	10·97
Salts of soda	16·33	1	10	0	1·78
	42·10			12	9
2. *Mechanically suspended.*					
Nitrogen	2·84	70	0	1	6·60
Insoluble phosphate of calcium ...	1·84	8	0	0	1·57
Organic matter	14·00	0	10	0	0·75
	18·32			14	5·92

The money value of the sewage of a town of 100,000 inhabitants would be about £50,000, the ingredients being valued at the rates above given, which are somewhat under the present prices of the chief constituents of artificial manures. The sewage of London has been valued at £4,000,000 by Baron Liebig; and estimating one ton of it to be worth only 1d., Dr. Corfield assumes it to be worth £1,108,333 6s. 8d. per annum. The quantity of sewage produced annually in Dublin I find, by careful calculations, to amount to 30,000,000 tons, the population of the city and its immediate suburbs being under 300,000.

The value of the sewage of a town may be approximatively ascertained by determining the value of the excreta of an average unit of the population. If the amount of fertilising matter obtainable from a single individual be worth 10s. per annum, the sewage of a town of 100,000 inhabitants would be worth £50,000, minus the value of the small amount of refuse carted out of the town. According to Dr. Thomas Anderson, the excreta of an adult male is worth 8s. 6½d. a year, and that of an average unit of the population 6s. a year. Dr. Hoffmann assumes the excreta of an average unit of the population to be worth 10s. 10d. per annum.

As the value of a ton of sewage is estimated at from ½d. to 2½d. per ton, it is evident that it must be applied in large quantities, and in a very inexpensive manner. The sewage of Edinburgh has for about two centuries been allowed to flow over the meadows close to the city. Some fields receive several thousand tons per acre,* and yield nearly 70 tons of grass, worth about £35. The sewage of Edinburgh flows by the force of gravity alone from the city to the irrigated lands, and the profit derived from it is about £7,000 a year, which helps to defray the municipal expenses. The sewages of Carlisle, Leamington, Mansfield, Malvern, Worthing, Croydon, Walford, Warwick, North London, and other places, formerly allowed to flow into rivers, are now employed in irrigating "sewage farms." The results have on the whole been encouraging, and especially so in the case of Croydon. In every town where the sewage has been utilised for agricultural purposes, the health of the inhabitants has been improved, an abominable nuisance has been abated, and, as a general rule the sewage works have proved, or give promise of proving, reproductive undertakings.

With respect to the agricultural value of town sewage when applied in sufficient quantity, there is now no doubt. It has been used with almost every variety of farm and garden produce, and with good results. At Barking Creek sewage farm, thirty-six different kinds of crops have been grown with the aid of London sewage alone. It has been alleged that sewage manure cannot be utilised on arable land, but this allegation rests upon the assumption that the liquid cannot be economically applied by means of pipes and hose and jet. Where, however, a regular sewage farm is established, such as that at Norwood or Barking, there is no reason why every kind of crop

* According to Dr. Anderson, 14,000 tons is the average quantity applied per acre.

could not be grown, even on the stiffest soils. Root-crops of excellent quality and most abundant quantity have been obtained by the sole aid of sewage; and according to Professor Voelcker, beets grown at the Lodge Farm, near Barking, contained 13·19 per cent. of sugar, whilst the best roots grown in Scotland, Holland, and Suffolk yielded only from 9 to 10 per cent. of saccharine matter at the outside.

In 1861, a committee was appointed by the Royal Commission on the sewage of towns to experiment at Rugby. The object was to ascertain the quantity and composition of the grass produced on land, a portion of which was unmanured, whilst to other parts were applied respectively 3,000, 6,000, and 9,000 tons of sewage per acre. In the following table some of the results obtained are given:—

PRODUCE GIVEN TO OXEN.

Plot.	Sewage required per Annum.	Actually applied to end of October.	Total Grass per Acre.				Increase of Grass per 1000 tons Sewage applied.			
			tons.	cwt.	qrs.	lbs.	tons.	cwt.	qrs.	lbs.
1	——	——	9	5	3	5	—	—	—	—
2	3000	1,872	14	16	3	8	2	19	1	7
3	6000	4,423	27	1	0	10	4	0	1	9
4	9000	6,153	32	16	3	8	3	16	2	9

The nutritious properties of the sewage-grown grass were proved by experiments, the chief results of which are given in the following table:—

Sewage applied.	Numb. of weeks the produce kept a Cow.	Gallons of Milk per Acre.	Value of Milk at 8d. per gallon.			Value of Milk from increased Produce of 1,000 Tons Sewage.		
			£	s.	d.	£	s.	d.
—	19·0	321·0	10	14	3	5	0	0
1,387	40·9	570·7	19	0	6	5	19	10
2,804	58·8	820·4	27	6	11	5	16	8
4,226	68·9	961·3	32	0	10	5	0	11

These experiments show that the application of sewage was attended by a great increase in the produce of grass. "Deducting the value of the milk produced from the grass of the unsewaged from that from each of the sewaged acres, reckoning it at 8d. per gallon, it appears that where about 1,400 tons of sewage were applied during seven months, the produce calculated, for each 1,000 tons of sewage actually applied, gave an increased amount of milk to the value of £5 19s. 10d.; where twice that amount of sewage was applied, £5 16s. 8d.; and where three times the quantity, £5 0s. 11d." The milk obtained from an acre of unsewaged grass was only worth £10 14s. 3d., whilst that obtained from the most highly sewaged grass was worth £32 0s. 10d.

The experiment was carried out under the observation of Mr. J. B. Lawes, the distinguished agricultural investigator.

The fact that sewage is capable of supplying the wants of every kind of crop is clearly established, but that which appears to be best adapted for sewage irrigation is Italian rye-grass. From six to eight heavy crops of this plant may be obtained from even exceedingly poor soil. Should the method of drying grass by artificial heat, now slowly coming into use, become general, enormous quantities of grass might be produced on the sewage farms, and at once—whether the weather be wet or dry—converted into hay.

The quantity of sewage applied per acre varies from a few hundred tons to perhaps nearly 20,000 tons. Mr. Lawes states that if he got sewage for nothing, he would apply 70,000 tons per acre; whilst other authorities contend that excessive quantities are injurious, rendering the land marshy, and producing a coarse and innutritious herbage. Mr. Westwood, late farm bailiff of the schools at Anerley, states that he obtained as good results from 1,500 tons of sewage applied to two acres of Italian rye-grass, as from 8,000 and 9,000 tons applied to equal areas of rye-grass. On the whole, it would appear that there is nothing to be gained by pouring more than 3,000 or 4,000 tons of sewage over an acre of land under any crop.

It has been proposed to substitute the system of earth-closets for water-closets, in the larger towns, in order (amongst other objects) to obtain the excreta of the population in a portable form. It is not, however, at all probable that the water-closet system, which possesses so many advantages over any other, is likely to be superseded by the earth-closets. Nor is it at all likely that the corporations of towns would make any profit by supplying fresh earth to the citizens, and receiving it back commingled with manure. The *poudrette*, or prepared human manure, used in France, which sells at 47 francs per cubic metre, costs in reality, according to Krepp (a good authority), 146 francs. At Manchester, the municipal authorities take upon themselves the task of removing all the waste matters produced within their jurisdiction. They sell the manure collected from the houses, and send it even so far as Lincolnshire; but they do all this at a cost of more than £10,000 a year to the ratepayers. In Glasgow, where there are special arrangements made for collecting human excreta unmixed with other matters, the city manure is valued for £18,000 a year, whilst the cost of removing it and cleansing the city is set down at £27,000.

Various plans have been proposed for the purpose of separating the valuable solid matters contained in sewage, but none of them have proved decided successes. It has lately been suggested to precipitate the nitrogen and phosphates by means of a solution of aluminic phosphate. A manure prepared according to this method has been variously estimated at from nearly £3 to more than £7 per ton. The A B C process consists in adding to the sewage a mixture containing blood, alum, clay, charcoal, oxide of manganese, and some other matters. It has been extensively tried, but with rather unsatisfactory results; but an attempt to demonstrate its advantages is now (September, 1871) being made at Crossness, a projection of the southern shore of the Thames, between Plumstead and Erith marshes. The experiment is being conducted under the supervision of the Metropolitan Board of Works, but it is not as yet sufficiently advanced to afford positive results. The promoters entertain the most sanguine hopes as to the ultimate success of the A B C process, and the product is to be sold (some of it is now in the market) under the name of "native guano." Carbolic acid compounds are added to sewage manure, but merely for the purpose of preventing foul effluvia from emanating from it. A very good manure is obtained by allowing the sewage to deposit its insoluble portion in a tank.

SANITARY ENGINEERING.—IX.

WARMING BY WARM WATER.

THE mechanical appliances for conveying heat and for distributing it in the most convenient manner are many and various. We propose to deal with them in a series of three or four papers, taking in each case one particular branch of the subject, *e.g.*, warm water, the heading with which we commence (*i.e.*, water below the boiling point, 212°); then hot water (water confined and heated to various temperatures up to 500°); and afterwards hot air and steam, as applied to similar purposes. The application of warm-water circulation to the purpose of heating baths, public and private, was in use in the time of the Romans, and there are several descriptions extant of vessels and coils of pipes used for the purpose; but in this country the process is of comparatively recent introduction, the first record we have of any authority being of a conservatory heated from a design of the Marquis de Chabannes, about the year 1818.

The first principle or motive power upon which all systems of circulation of water for heating purposes are founded is that hot water is lighter than cold, and naturally rises to the surface of a vessel heated from below. Perhaps one of the simplest forms of the principle is that adopted in heating an ordinary bath with a small stove or cockle, the boiler, above the fire, containing a small quantity of water, and communicating with the body of water in the bath by an upper and lower pipe, commonly called the flow-pipe and return-pipe. As the water becomes heated in the boiler it rises to the surface, and passes out through the flow-pipe into the bath, its place being gradually supplied by the entrance of the cold water through the lower or return-pipe. As long as the fire is kept up the motion is constant, as the water in the bath constantly loses heat by exposure to the air; while, for the same reason, it can never

rise above the temperature of boiling water (*i.e.* 212°), as at that point it is converted into steam and evaporates. This, however, is not likely to occur, as the ordinary temperature of a warm bath rarely exceeds 100°, and scarcely ever 105° or 106°. This principle has been carried one step further as applied to heating conservatories and greenhouses, by allowing the water to circulate through a series of open channels or troughs dispersed about the building; but the system had several inconveniences, especially arising from the necessity of maintaining an absolute level throughout, and never came into general use.

The form in which it is generally applied is, by availing ourselves of the circulating power of heated water above alluded to, to conduct the water through a series of pipes, either extended in a line or arranged in a coil, but in every case starting from and returning to the boiler with a flow and return. Considerable difference of level can thus be gained, the requisite strength of apparatus being provided; for it must be always borne in mind, that for every additional foot in height to which the water has to be carried a considerable extra pressure on the boiler is the result. For ordinary purposes, this may be taken as a pound of pressure for every two feet in height (the actual carefully calculated result being in fact some per-centage lower) on every square inch of surface. The dimensions of the pipes make no difference in the result, as it is a well-known fact in hydraulics that the pressure of a column of water is regulated by height alone, independent of area; but in every case, at the topmost point of the system, there should be a communication with the external air; and in cases where one part of the pipes dip below the other air-vents should be provided, as otherwise steam will probably be generated, interfering with the circulation, and inducing the risk of explosion. The introduction of these air-vents should always have the most careful consideration of the engineer.

The construction of the boiler for warm-water apparatus has occupied much attention. We have at the moment a work before us in which twenty-eight different varieties of form are illustrated on a single page; and therefore shall confine ourselves to the remark that the old-fashioned horse-shoe form, in which the fire is lighted under the arch, and passes to the flue at the back, has many advantages, and is in general use at the present time; while where it is desired to make available, as is often done, the heat of the kitchen fire for warming a bath, or a coil of pipes in the hall of the house or on an upper storey, an ordinary wrought-iron boiler of sufficient strength, passing at the back of the range, will answer the purpose perfectly well. This closed boiler may be made to communicate by means of pipes with an open boiler at a higher level, from which a supply of hot water for any purpose can be obtained. This system was introduced by the Marquis de Chabannes, in 1818. In all systems of apparatus on this principle, care must be taken in the fixing of the pipes to provide for the expansion of the pipes caused by the increased temperature. Cast iron, the material now most frequently used, when raised from 32° to 212°, expands about one nine-hundredth part of its length, or rather less than $1\frac{1}{2}$ inch in 100 feet. In horizontal pipes it is usual to provide small rollers at the points of support, over which the pipes can move, as if permanently fixed constant ruptures of the joints are the result. The rate at which the water can be made to circulate through the pipes is a matter of careful and tabulated calculation, varying with the heat of temperature and the size of pipe; friction, as it is technically called, having a most important bearing upon the result. Experience shows that the friction in a 2-inch pipe is double that of a 4-inch, and in a 1-inch pipe four times; and it should always be borne in mind that water when heated expands. It has been shown by experiment that water raised about 100 to 150° above its previous temperature gains from a thirtieth to a fortieth part of its bulk; in all systems of apparatus this should be provided for, or an overflow will be the result.

We now proceed to give a few data in reference to the comparative powers of different sizes of apparatus. It has been ascertained by experiment that four square feet of boiler-surface will evaporate one cubic foot of water in an hour; and, by calculation, it will supply sufficient heat to keep over 200 feet of 4-inch pipe up to 140°. We may take as a rough guide, then, 1 foot of boiler-surface exposed to the fire for 50 feet of pipe. As a result deduced from similar experiments, we may say that 10 feet of boiler-surface will heat 500 feet of 4-inch pipe, or 666 feet of 3-inch, or 1,000 feet of 2-inch; while 20 feet will heat 1,000 feet of 4-inch, 1,333 feet of 3-inch, or 2,000 feet of 2-inch.

Then, as to the area of the furnace under the boiler, quality of coal, heat of atmosphere, rate of draught, and various other circumstances exercise varying influences, therefore the figures given must only be considered as approximate; but we may say that 1 square foot of furnace-bar will burn 10 lbs. of coals per hour, and on this calculation we may base the following statement:—That 100 square inches of furnace-bar surface will supply 200 feet of 4-inch pipe, 266 feet of 3-inch pipe, or 400 feet of 2-inch pipe; that 200 square inches will supply 400 feet of 4-inch, 533 feet of 3-inch, or 800 feet of 2-inch; while 500 square inches of area will heat 1,000 feet of 4-inch, 1,333 feet of 3-inch, or 2,000 feet of 2-inch.

Having thus given a few data as to boiler and furnace, we now take up the question of the quantity of pipe required to produce a given result. Our limits will not allow us to treat this question at length, as it is necessarily a voluminous one, involving the different regulations of temperature required for different purposes, *e.g.*, dwelling-houses, workshops and manufactories, greenhouses, pineries, conservatories, etc., and another most important development of the system for churches and public buildings. It is evident that a totally different set of conditions exist in each case, and that they must be differently dealt with, though the same general principles apply throughout.

Tables have been published showing the quantity of 4-inch pipe which will heat 1,000 cubic feet of air per minute any required number of degrees, the temperature of the pipe being 200°. The table is too long for insertion, but we will give a single example of its working. Suppose the temperature of the external air at 40°, and the temperature at which the room is required to be kept is 80°; the number of feet of 4-inch pipe to each 1,000 cubic feet of air should be 187. Having thus given the general data upon which warming by hot water is carried out, we may conclude by noticing one or two recent adaptations of the principle on an extended scale, showing of what development the system is capable, and how one apparatus may be used for various purposes.

At a mansion in the neighbourhood of Manchester, completed in the course of last year, a system of warm-water apparatus is applied throughout the whole of the premises, which cover a total area of 700 feet in length by 200 feet in width, and contain ordinary dwelling-rooms (for which the calculated temperature required is from 40° to 50°), halls, corridors, a picture and statuary gallery, and a billiard-room; then the stables and coach-houses, greenhouses, the vineries (requiring according to weather and circumstances a temperature of 40° to 70°), and, lastly, the orchid houses, where a constant heat of 70° to 80° must be maintained.

The warming-power consists of three large tubular boilers, 7 feet high, so arranged that they can be used separately and interchangeably, one being sufficient for summer use and two for winter, the third being provided in case of accident or repair. The principal flow and return mains are 6 inches diameter, and each special room or department has its set of pipes, varying in size and length, flow and return, communicating with these mains by means of valves, which can be opened and shut at pleasure. The quantity of superficial area of pipe required for each special purpose is regulated by the temperature required to be maintained upon the principle before indicated; in some cases two lines of pipe are sufficient, and in others there are as many as ten. The number of sets of pipes throughout the establishment is fifty-four, and the total length of pipes used approaches 15,000 feet. We may mention that the cost of the apparatus was about £600. In this case the buildings are almost all upon one uniform level, the difference of height between the lowest and highest pipes being about 7 feet.

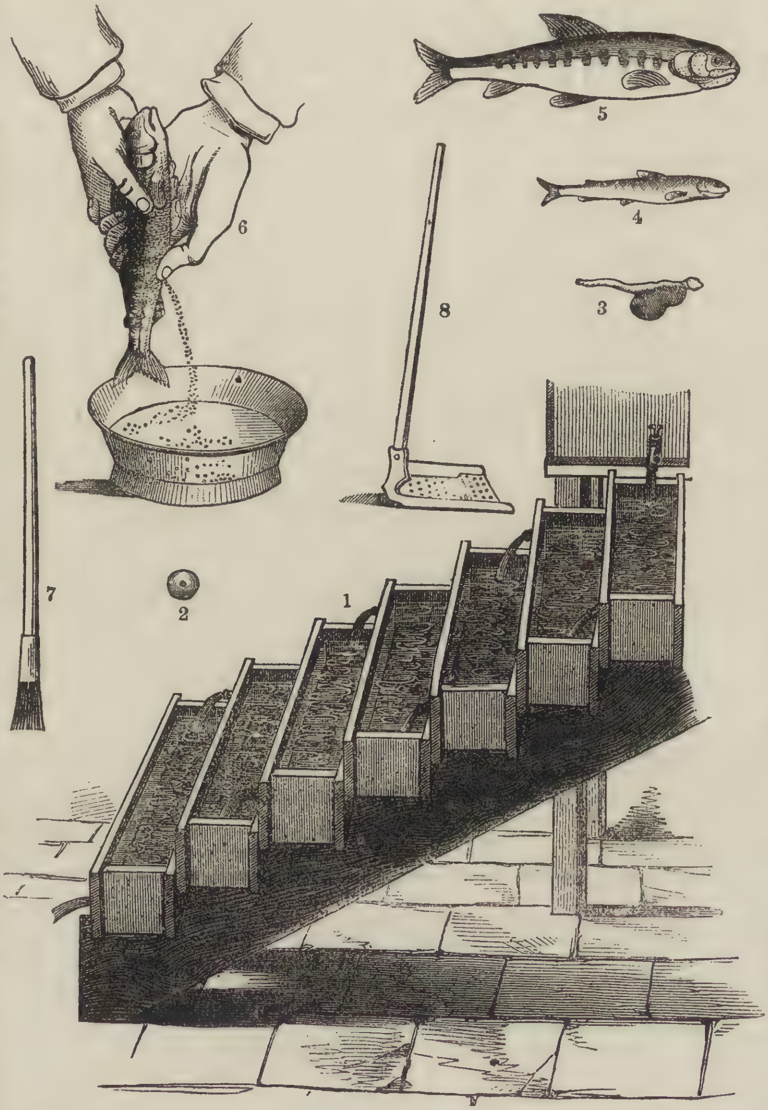
Another instance of a still more extensive application of the system may be seen at the gardens of the Zoological Society, in the Regent's Park, London. To its application to factories and workshops generally—a most extensive and important branch of the subject—we can only allude, our object having been to explain the general principles of the subject, and to give as concisely as possible some of the generally accepted data upon which are founded the principles of our modern practice of warming by warm water, *i.e.*, water under boiling-point or 212°. The average heat worked up to may be taken in practice from 140° to 180°, when the apparatus is in ordinary working.

FISH CULTURE.—I.

By Greville Fennell.

ORIGIN OF FISH CULTURE—SALMON-BREEDING—REARING-TROUGHS, ETC.

Writers upon the art of fish culture would date the discovery far back into remote ages, and give the merit of the commencement of the practice to the Chinese, but the much vaunted fish culture of this nation consisted merely in collecting the eggs of fish from their natural spawning-beds or while floating in the water, and selling them to the fish farmers, who again deposited them in their paddy fields, and thus obtained a means to renew the stock of their canals and ponds. It may be said in passing that there are no salmon in China, although there are plenty in Japan; and we hear nothing of fish-hatching in the latter country. All sorts of stories are current respecting the ingenuity of the Celestials, and of course they would not be wanted to adorn this subject of their pursuits. Amongst other expedients resorted to, it is said that, when the proper season for hatching has arrived, they empty a hen's egg, by means of a small aperture, sucking out the natural contents, and then, after substituting fish spawn, close up the opening. The egg thus manipulated is placed for a few days under a hen! By-and-by the shell is broken, and the contents are placed in a vessel of water, warmed by the heat of the sun only; the eggs speedily burst, and in a short time the young fish are able to be transported to a lake or river of ordinary temperature, where they are, of course, left to grow to maturity without being further noticed than to have a little food thrown to them. This wonderful fish and egg process is suggestive of the fact that all our efforts in this country to imitate the boasted success of the Chinese in the rearing of fowls by artificial incubation have been attended with signal failure and great loss.



Refs. to Figs.—1. Boxes for artificial salmon rearing. 2. Egg, showing oil-globule. 3. Young fish, showing umbilical bag. 4. Young salmon after being fed from his umbilical bag. 5. Young salmon fully developed. 6. Method of taking eggs from fish. 7. Hair pencil for taking fish from egg. 8. Small perforated shovel for lifting the fish first hatched, to transfer to the running streams or nursery.

It has been truthfully observed that the great merit of a discovery consists in making it useful and of benefit to mankind; and such being admitted, we leave others to contend for the honour of the first idea, and introduce Messrs. Gehin and Remy to our readers. These men were poor fishermen living by their calling in the commune of Bresse, in the department of Vosges. It is evident their brains were as active as their hands, for it had long puzzled them how animals yielding such an abundant supply of eggs, should by any amount of fishing ever become scarce. They knew very well that all female fish were provided with tens of thousands of eggs, and they could not see how, in the face of this fact, the rivers of La Bresse should be so scantily supplied with the finny tribes. Nor was the scarcity of fish confined to their district: the rivers of France generally had become impoverished; and as in all Catholic countries fish is a prime necessary of life, the want, of course, was greatly felt. Thus these men were the first to find out what was wrong with the French streams, and especially with the fish supplies of their native rivers; and better than that, they set about to discover a remedy.

It was about the year 1841 they commenced to observe carefully the habits of the trout, and in the month of November of that year, during a full moon, they passed night and day on the banks of a river, never for an instant losing sight of these fish, and watching most intently all their preparations for laying and preserving their eggs.

The results of their observations were these.*

"The trout come together in a shoal, and choose a current with a gravelly bottom as the best place to lay their eggs. They did it in a round hole, sometimes of the depth of seven inches by three in diameter; they place in the middle of this space, parallel with the current, a line of stones, the size of which varies with the size of the fish. The female then passes over the line of stones, gliding over, rubbing against, or resting upon them. This she does again and again, some twenty or thirty times, till her eggs are all laid in the crevices of the gravel.

"When the female has done this, the male in the same manner, by passing over and pressing upon the gravel, unites the milt, or soft roe, which covers and fecundates the eggs; then with tail, fins, head, and belly he works away until he manages to cover the eggs with gravel.

* *Vide* M. Godenier's report prepared from facts furnished by M. Gehin.

"Now a second female commences, and in the same manner lays her eggs in a parallel line with and against the first row. When the fecundation is complete, which generally happens in about fifteen days, according to the number of fish, all unite in heaping up stones and gravel in mounds upon the eggs, in a manner resembling great ant-hills.

"The eggs remain in this way for a month or two; at the end of that time, which M. Gehin could not precisely determine, the little fish appear about the size of pins, come out of their cell, between the interstices of the gravel, and seek in the tranquil waters near the shores a place of safety.

"Having thus got an insight into Nature's secrets, it remained to discover a mode of rendering them practically useful, and not until many failures did Gehin and Remy hit upon a sure process."

It was necessary at that time in France, if not now, in consequence of the system of centralisation existing in that country, that discoveries, to be known at all, should have Parisian and governmental sanction. So it is not surprising that this one of artificial fish culture remained unnoticed and unknown until 1849, when having chanced to come to the knowledge of Dr. Haxo, a scientific man residing in the same department as the two fishermen, it was by him communicated to the Academy of Sciences at Paris in a paper, which caused a great sensation in that learned body, and hence the foundation of the College of France under the management of MM. Coste and Coumes.

Thus public attention was called to pisciculture, which may be briefly described as the art of fecundating and hatching fish eggs, and of nursing young fish under protection till they are of an age to take care of themselves, and the subject was earnestly taken up in France and Great Britain. Many works by as many different authors were published on the subject, notably those in France by Coste, Godenier, Haxo, etc.; and in England by Shaw, Andrew Young, Boccius, Francis Francis, Frank Buckland, Buist of Perth, etc., and shorter essays by several others. To show, however, as a contrast to this ready and active adoption of the discovery in France, the apathy with which it was received in America, Mr. W. H. Fry, writing from New York in 1854, says, "Agriculturists on this side of the ocean are beginning to wish for light, but none was to be had; and proving how slowly the knowledge of great truths sometimes travel, not a copy of any of the publications which have met with so much attention in the mother country is to be found at any of the booksellers in New York."

Bertram says some dispute the claims of France to the honour of this discovery, asserting that the peasant Remy had borrowed his idea from the experiments of Shaw of Drumlanrig, who had by the artificial system undertaken to prove that parrs were the young of the salmon. But the honours may be thus divided. Whether Remy knew of Shaw's experiments or not, let Scotland have the honour of re-discovering pisciculture as an adjunct of science, and France the useful part of having turned the art to commercial uses. Shaw in 1840 published a very valuable book upon his operations,* in which the discovery that the parr was the young of salmon is fully treated upon, as grilse was the intermediate stage of salmon. Since these days the observations of Mr. Milne Home and the Tweed Fishery Commissioners in marking fish have added much to the knowledge of our migratory Salmonida.†

As this process has since Gehin and Remy's operations undergone certain alterations and modifications, without, however, affecting in the least the grand basis of a principle they so definitely laid down, we would rather refer to the *modus operandi* at present pursued than to the past. The best mode of hatching eggs, the cleanest and least expensive, is that which has been adopted by Mr. Ponder and Mr. Frank Buckland (and was formerly practised by Mr. Francis Francis) at Hampton, and at the Museum of Economic Fish Culture, Kensington.

Artificial spawning for salmon is very simple. All that is required is to obtain as many female fish or spawners as are deemed sufficient to produce spawn enough to restore the river. Some works of pretension tell us that the males are more scarce than the females; but experience and observation teach us the remarkable fact, that amongst all salmon and trout spawning-beds, the contents of the nests will be found to contain seven cocks to one hen. This is the more to be observed in those rivers in which the weir stops the fish from ascending into the more ample and more natural, and consequently more acceptable spawning-grounds. In the pools of such weirs they crowd together, and as the fish cannot hold their spawn when fully ripe, they fight and hustle each other for an appropriate place; and in this way not only are the ova scattered about, and in most instances entirely wasted, but the fish are much injured by fighting, and seldom or never, as is well known with most fish, recover even from the slightest bodily flesh wounds. Hence the great importance of salmon ladders to admit of their reaching a greater field of operations in which they may begin and finish their interesting and profitable duties without hindrance or molestation.

The principal thing to attend to is to take the female at the right time, and this is when she is working high up stream; for though some females return nearly ready to spawn, the greater number make for the springs some time before they are full gone, and ripe for parturition. You may easily know when a fish is full up, and in condition to have her eggs taken from her, by looking out for the redness and pear-shaped protrusion of the vent; and this must be particularly attended to, or the mother may be destroyed in the operation. The small fish are the first to spawn. The larger ascend later; but it is always advisable to obtain, if possible, a young male and an old female, as the brood are always the best.

Artificially bred salmon are always round and big-headed creatures, no matter how handsome and small-headed the parent fish were from which the ova and milt were taken.

In migrating time the young become as wild as nightingales, and attempt to leap their barriers. To prevent injury and loss, boards slanting inwards should be placed so that they may fall on them and be thrown back into the water.

Mr. Buckland, in his recent report upon the Scotch Salmon Fisheries Inquiry, 1871, and which thus far applies equally to other parts of Great Britain, says the conclusions he has arrived at relative to artificial breeding of salmon are briefly as follows:—"Firstly, that the plan of slate or wooden breeding boxes placed one above the other, and fed by a half-inch tap, is much preferable to boxes let into the ground. These boxes should contain almost one-third of their depth of fine gravel; the gravel should be well washed *and boiled* before being put into the boxes. Covers* of wood should be placed over the boxes to keep out the light, as *light is unfavourable* to the germination of the ova. The great advantage of these boxes is, that the eggs can be counted into them, and the young ones counted out, so that the result in the number of fish hatched can be clearly known (of course taking stock of the addled eggs removed), a matter of great uncertainty in the rough out-of-door boxes. The eggs can also be easily removed as they die off.

"Secondly. The young fish should be turned out when the umbilical bag is nearly absorbed. They should never be let free in ponds or anything approaching to stagnant water. The best plan is to put them into cans, the water of which should be kept cool during the journey with ice, and send them to the upper waters of the tributaries of the river. V-shaped weirs directed up stream should be built with the stones in the stream, and a large stone, slate, or covering should be put over the arms of the V, so as to form a hiding-place for the young fish. From five to ten little fish should be put into each of these artificial hiding-places. Fish thus turned out grow much faster than fish kept in any sort of captivity; they obtain of their own accord the quality of food, and the superintendence of a man to look after the nursery ponds is saved.

* Adam and Charles Black, Edinburgh.

† *Vide* "Salmonoids of Tweed." Blackwood, 1867.

* The use of lids to the spawn-boxes is to prevent water-fowl, kingfishers, and herons from peculation, and keep the prying curiosity of individuals from disturbing the eggs, which is pretty sure to end in their becoming addled. Many over-wise experimentists wonder that the results of their exertions are not as successful as others'; but we think it can be shown that, after the first process is completed, the less we meddle the better. It may be necessary, of course, occasionally to remove the addled eggs, but this should be done as quietly as possible. Birds will desert their nests, and even their young; rabbits will devour their progeny; and even a motherly hippopotamus will not tamely submit to have her domestic arrangements pried into, even by great naturalists, without indignation at such impertinence, as one was recently known, on being debarred from getting at the actual culprits, to turn her anger upon her innocent "baby."

"Thirdly. The slate rearing-troughs can be set to work in gardens, stable-yards, greenhouses (where there is no fire), or any other suitable locality under cover, where there is a cistern or other water-supply large enough to afford the requisite flow of water. The quantity flowing through a half-inch pipe day and night is quite sufficient.

"Fourthly. Natural obstructions or even small waterfalls in private gardens may be easily rendered available for hatching fish. When the fish come to the obstruction, they should be netted out from the pool below, their eggs taken from them, and returned to the river; the boxes being arranged by the side of the waterfall, a leaden pipe with a stopcock can be easily introduced into the water above the fall, and thus be made available for the feeding of the boxes.".

A paragraph in this admirable report, one of the most thoroughly practical and interesting which has ever emanated from any board of pisciculture, fully coincides with our own views.

"Though I advocate," says Mr. Buckland, "the multiplication of salmon by every possible means, I do not for a moment wish it to be imagined that artificial breeding of salmon can ever be of as great importance to the rivers of Scotland as the opening up of fresh spawning-ground by the removal of obstructions, natural and artificial, provided that the fish were properly protected in waters so opened up."

The boxes of which we give an illustration (Fig. 1) can be procured ready made at the Kensington Museum.

The gravel should be about the size of large peas, and the proportions should be one-third gravel to two-thirds depth of water. The dead eggs are best removed with a wire forceps, which should be done every day. The current of water should be gradually increased. Pisciculturists differ as to the best time of turning out the fry, some being for doing so before, others at the time, and some few after the umbilical bag has been absorbed. The upper waters of natural streams in which the depth is not more than a foot or eighteen inches form the best nurseries for the young fry, but they should be regularly fed every evening, not in the middle of the day, as they will then refuse their food, and it will fall to the bottom and become stale. Plenty of water-weed should be placed in these nurseries, as they produce aquatic insects of which all fish are very fond, and on which they live and thrive. It is necessary to give the fish hides to go under and through in all stages after they come out of the egg. The hides can be easily made with pieces of common roofing slate supported about two inches from the bottom. The fish will invariably be found to congregate under them. The same water which runs through the boxes will do to supply the nursery, which is better out-of-doors than indoors. Water-cress beds are above all things most suitable for bringing up young trout.

But those who wish thoroughly to understand Mr. Buckland's apparatus should endeavour to have an opportunity of examining it in full working order, when possibly there may be seen one, two, and three-year-old salmon and trout in the nursery, and in another box, perhaps, salmon of six years of age. There are boxes which will hatch out 3,000 fish. This description of apparatus has been at work for many years at Windsor Great Park, where the best results in practice have been obtained by the stocking of the Obelisk Lake with trout. It is interesting to know that fish have frequently been caught there with a fly-rod. These experiments, or rather results, have been carried out by Mr. Buckland under the direction of H.R.H. Prince Christian, ranger of the Park, and Mr. Menzies, the deputy-surveyor. The eggs in general have been supplied from Huninguen; but as this famous piscicultural establishment was turned into a stable for the Prussian cavalry during the late war, other sources had to be sought, and were found without any difficulty. The restoration of Huninguen and a re-continuation of its operations will be touched upon presently. Mr. Buckland has also obtained many eggs from Aberdeen and the Coquet in Northumberland, that gentleman visiting these and other rivers in the winter months, and personally operating upon the ripe fish.

When the young fish are ready to see the world, he sends them from Kensington to the rivers Severn, Wye, Usk, Axe, Exe, Fowey, etc., by night train, in lots varying from 200 to 500. They travel in Welsh tin milk-cans. A salmon caught in the Tay, which was said to be a Rhine-fish, was sent by Mr. Buckland as a fry. He, however, keeps many young fish in London to show the progress of growth. The great lake trout ova is obtained from Neufchatel lake in Switzerland; they are sent over when the eye is visible in the egg. Those great lake trout are found to grow fatter and faster, and thrive better than any other Salmonida.

Similar apparatus more or less important to those at work at Kensington are and have been in operation for the past few years at the Duke of Marlborough's, at Blenheim; Lord Exeter's; the Earl of Stamford and Warrington's; also at the Hon. W. Fitzwilliam's, where large numbers of salmon have been hatched and turned into the Nene. The Canterbury commissions of the Stour, and Mr. Clifford, constable of Arundel, have likewise availed themselves of the like mode; the latter, however, we are sorry to say, with indifferent success. The *salmo fortunalis* at Kensington were sent as ova by Mr. Seth Green, of New York. They have done well in the nurseries. Mr. Buckland has also received hybrids between charr and trout from Sweden.

We have mentioned the umbilical bag. This is found attached to the belly of the young fish, when it quits the egg, and is situated between the pectoral fins (Fig. 3). It contains oil-globules and albumen, and serves to nourish the fish for at least six weeks. When it is absorbed, the fish begin to feed, but not before. Often the little fish stick in the egg, and have to be helped out of it, which can be done by the delicate manipulation of a hair pencil (Fig. 7). Some trout eggs are the colour of barley-sugar, and some of brown barley-sugar. After the mixture of the milt, they have a bloom come over them, like that of a peach, and they likewise become slightly adherent to the stones about them. The oil-globule in the centre of the egg can be seen from the first moment (Fig. 2). The test of a ripe egg, says Mr. Buckland, is this: put one in the mouth, and if you can crush it with the teeth it is not ripe; but if the covering of the egg feels hard and horny, and slips away from between the teeth, the egg is ripe.

After the eggs have been taken from the fish (Fig. 6), the parents will be found extremely faint, and the manipulator must be very particular in holding them for a short while with their heads up stream, and slightly raised, that they may receive the revivifying effects of the current, or they will die, and the operator receive discredit from the owner of the fishery.

Years since, when the subject of pollutions was agitated, and the unavoidable consequences which must result from the conversion of our rivers into cesspools pointed out, those blindly ignorant, wilfully perverse, or selfishly interested, designated tauntingly the cause of the advocates of purity with the intended-to-be derisive term of an "angler's question." No greater compliment, although not purposed as such, could have been paid to the contemplative art. It was indeed an angler's question, but not only so because it was a question that concerned all classes, the consequences of which must sooner or later come home with crushing force to those obstructives to the cause of cleanliness, who had hitherto opposed every sanitary effort, and maintained their will until they themselves had to abandon their own dictum or hold their tongues in the midst of the deplorable state of things they had done their utmost to create and perpetuate. As the importance of the purity of our streams was an angler's question, so was fish culture, the one being inseparable from the other. And as the subject of permitting our sewage to enter our rivers grew in magnitude and importance, so did the anxiety not only of the angler increase for the safety of the fish; but the Legislature, at length aroused to action, stepped in and declared that pollution should no longer go on; that whatever the community did with its sewage, it should not be cast into the waters to defile an element of vital consequence to all. Thus far the angler's gratification, the people's food, and the healthful character of the water thousands are compelled to drink in the state in which they find it, became intimately blended, and, as in most other cases, the good of the unit became the interest of the many; and the fact that a wrong cannot be done to one without affecting all, received another illustration.

Fish culture, as we have said, is not a question of angler only, but of the health of the people, particularly in these times, when medical investigations show that the germs of cholera and other diseases are carried and disseminated by water, which no amount of filtration will get rid of. All the towns above any established water company should be placed

under injunction and at once. No plea for time or excuse for procrastination should be allowed to prevail. Sewage of every class, refuse of bleachings of paper or printing mills, the petroleum on the Dee at Chester, the flax dressings and steepings of Scotland, the débris of the lead mines upon the Welsh rivers, the China clay of Cornwall, the esparto washings of our pulp factories—indeed, all and every abomination or substance foreign to water—should not be permitted to enter our streams and rivers. The practice is monstrous and unnatural, and is fraught with serious injury to all, and should be stopped at every hazard. The honest, the fairest course is obvious. Let the manufacturer put the water back in the same state that he received it, or deny him the privilege of its use. That he can comply with such reasonable conditions is admitted everywhere; it is but a matter of expense; and it is but just that such expense should fall upon those who benefit by the use of the water, and that neither those to whom the water belongs in common, or the water itself, should suffer injury for any individual interest. It is to the credit of some mine proprietors that they have adopted catch-pits with great success, and Tavistock may be instanced as an example which must shortly be followed elsewhere. The "hush" or lead water in the Gloucester Severn and the Durham Tees is still very bad, and thousands of fish are annually destroyed by this stuff in the Ribble, in consequence of which the Hodder is now the chief spawning-ground. It has been urged that pollutions to a certain extent do not kill fish; but admitting this, it cannot be denied that they keep the salmon back, and thus decrease the rental of waters either from net or rodholders. It can never be too strongly inculcated, nor too often repeated, that the presence of fish is the best test of the purity of water, and therefore the more salmon our rivers contain the less will be the returns of our census of death from preventible causes.

MINING AND QUARRYING.—XIII.

BY GEORGE GLADSTONE, F.C.S.

STEEL.

DISTINCTION BETWEEN STEEL AND IRON—CEMENTATION—BLISTER STEEL—SHEAR STEEL—CAST STEEL—TEMPERING—CASE-HARDENING—CASTING STEEL ON IRON—PUDDLED STEEL.

ALTHOUGH steel is so familiar an article in our household economy, and is daily handled by almost every one from the days of their childhood upwards, it would puzzle most people to give a definition of steel, or to say wherein it differs from iron. In point of fact it is not altogether easy to give a definition, though as to some of its properties the distinction between it and either cast or wrought iron is very marked. Those which are peculiar to steel, and which impart to it a special value, are its high elasticity, and the extreme hardness which it can be made to possess by undergoing the process of tempering.

It may perhaps be best described as a carbide of iron, or a compound of iron and carbon, the proportion of the latter ranging between about 1 and 2 per cent. In the previous articles on iron, the presence of carbon has constantly been noticed; but there it will be found that the per-centage of carbon in pig iron is greater, and in the malleable iron less than what seems to be requisite in order to constitute steel.

At first thought it would seem therefore that steel could be produced even more readily than bar iron; but as a matter of practice this is by no means the case. The impurities of pig iron, which are only expelled by the expensive processes of puddling and forging, are still more objectionable to the worker in steel, and therefore the ordinary plan of making it is to take the very purest malleable irons that can be obtained, and re-carbonise them, in order to restore to them a portion of the carbon which they have lost in the previous stages of their manufacture.

Sheffield is the great centre of the steel trade; and for the purpose of this manufacture the finest iron is always used, by far the greater portion being imported from abroad. England cannot pretend to compete with some other countries, such as Sweden and Russia, in the production of such iron as is required in the making of steel, because it must not only be made from the very purest ores, but must also be smelted with charcoal. England does, however, not only compete with, but excel, all other nations in the quality and finish of her Sheffield wares.

The ordinary process of converting iron is by cementation, producing what is commonly known as blister steel. From this both shear and cast steel are subsequently made; the former of these is used for the inferior cutlery, and the latter for the superior, such as razors, penknives, surgical instruments, etc.

Steel can be produced by direct process from cast iron, though not of the quality required for the purposes above named; this plan, however, is largely practised in Germany and Austria, where the conditions of its manufacture are more favourable, as they have ores of the best quality and abundance of timber. The so-called Bessemer steel is made by only a slight modification of the process described in page 296, producing a metal of inferior value, but very useful for certain purposes, such as the manufacture of railway bars, and as a substitute for iron in shipbuilding. Several other processes are also adopted for making puddled steels of the same class, from both pig and wrought iron.

The converting furnace used in cementation is generally constructed as shown in Fig. 1. The bars of iron to be operated upon are laid flat in the troughs, A A, the bottoms of which are first covered with a layer of pounded charcoal (called cement) to the depth of about two inches, and then each successive layer of iron is separated by one of charcoal about half an inch thick, until the trough is nearly full, the uppermost layer of cement being closed down with an impervious coating of clay, or of sand mixed with iron filings. As soon as the charge is completed, the man-hole, B, is closed, and the furnace, D, is lighted, when the heated air, as shown by the arrows, passes up at both the sides C, C, and ends of the troughs, and fills the vault above, before escaping by the flues, E E, into the chimney. The temperature should be kept up at a bright red heat for about seven to ten days, according to the description of steel that may be desired; the fires are then put out, and the furnace left to cool gradually, which occupies some days. When the metal is taken out the bars are found to be covered with blisters, from which circumstance this kind of steel has derived its name. The quality of steel produced is judged by the appearance of its fracture, and it is assorted accordingly; the quality is found to depend very much upon the temperature of the furnace, and especially on the evenness with which that temperature has been maintained.

Steel, like wrought iron, possesses the important quality of being weldable; but its capacity in this respect is inversely proportionate to the quantity of carbon it contains. Before attempting, therefore, to weld together two pieces of steel, it is desirable to ascertain that they are about uniform in point of carbonisation, or a good result cannot be expected. Advantage is taken of its capacity for being welded in the manufacture of shear steel. The blistered bars are broken up into short lengths, made into a fagot, and bound together with an iron ring attached to a long rod, as shown in Fig. 2. The end A of the fagot is raised to a welding heat in a coke fire, and then beaten and drawn out under a tilt hammer, in the same way that malleable iron is forged; as soon as that is welded into a solid bar, the other end of the fagot is subjected to the same treatment, and a bar of shear steel is the result. Sometimes the bar is cut into two pieces, and these are welded together again, in which case it is called "double shear." A little sand is always sprinkled over the surface of the fagot before it is heated, in order to form a glaze, and so protect it from oxidation, which would involve a loss of some of the carbon, and tend to reduce it nearer to the condition of common malleable iron. Even with the greatest care some small loss of carbon will take place, and consequently shear steel is always wrought more easily than the blister from which it is made.

Cast steel is produced by melting blister steel in earthen pots or crucibles without exposure to the air. The great object of doing this is to obtain a perfectly homogeneous article, such as cannot be attained by forging. This is absolutely necessary for making instruments which are to possess the keenest edges, as the smallest flaw or unevenness of quality would completely destroy their value. The crucibles used for this purpose are made to hold about 40 lb. of steel at a time, and as each of them will only stand three meltings, the making of the pots themselves forms an important part of the operation. They are moulded out of very refractory clay, well kneaded with a small admixture of old ground pot and coke-dust, and when made are put into a heated chamber to be thoroughly dried. When required for use the crucible is placed in a small furnace, which is filled

in with coke, much in the same way as in assaying; and when brought up to a red heat, the charge of broken blister steel is introduced through a funnel, a little manganese being sometimes added, and the pot is covered with a lid made of similar clay. The furnace is then got up to its full heat, which is maintained until the steel is thoroughly melted; when the crucible is lifted, and the contents poured into ingot moulds to cool. The cast steel thus produced is very hard, and much more difficult to work; the effect therefore being precisely the opposite of that realised in making shear steel; the addition of a small quantity of manganese is considered to have the effect of increasing its malleability, and also of rendering it more easily welded.

There is still one process to which steel is subjected, which develops one of its most valuable qualities. It is the tempering. Steel becomes intensely hard by being heated to redness, and then suddenly cooled again by immersion in cold water, oil, mercury, or other liquid. Having thus been brought into this very hard condition, its hardness is then tempered by a repetition of the process only at a much lower temperature. The hardness of the metal will then be in inverse proportion to the amount of heat employed on the second occasion. Thus the best surgical instruments, which require the highest temper, are only re-heated to 430° or 450° Fahrenheit, good cutlery to 470° or 490°, the larger cutting tools to 510° or 530°, watch and bell springs to 550°; and saws to 560° or 600°.

Fig. 1.

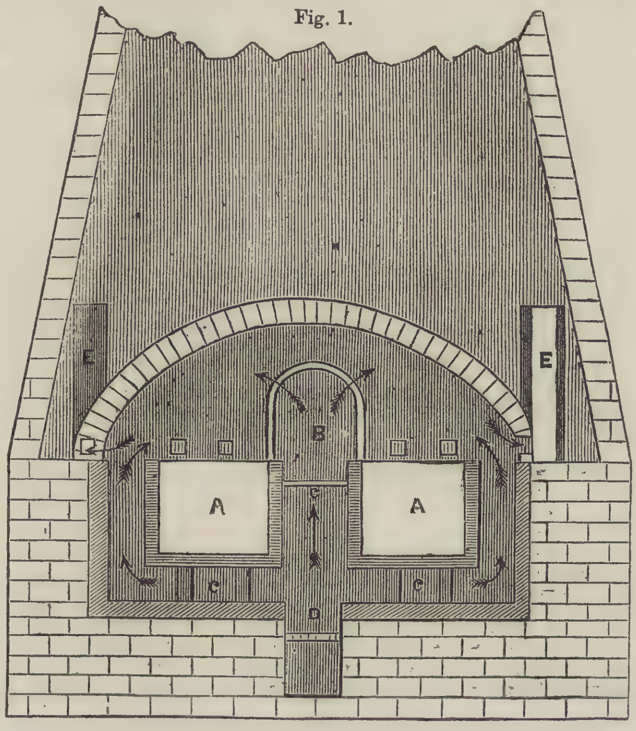


Fig. 2.

In this operation the workman may be guided either by the temperature, or by the colour of the steel. It is essential to good workmanship that the metal should be heated uniformly throughout up to the precise point required, which is most conveniently done by immersing it in a bath made of some article which has a suitable melting or boiling point. Thus linseed oil boils at 600°, the temperature required for ordinary saws, and can be advantageously used in their preparation. For lower temperatures a bath consisting of a mixture of lead and tin can be employed, the melting-point of which varies according to the relative proportions of the two metals. Thus 7 to 7½ parts of lead with 4 of tin will melt at the heat required for the best surgical instruments; 5 to 7 parts of lead with 2 of tin will give the temperature required for good cutlery; 12 of lead to 1 of tin that needed for watch springs; and so forth.

The colour of the steel, is however, the most ready test, and it is so characteristic that to some extent it must be familiar even to those who are ignorant of how or why it is produced. The beautiful purple or blue surfaces of axes and saws may be observed on looking in at the window of any tool shop; but even the shade of the blue or purple will tell the practical man at what temperature between 510° and 600° the different articles have been tempered. The other articles of finer or coarser cutlery all exhibit their characteristic colours before they are ground, those most highly tempered being of a pale straw colour, and then passing up in succession through yellow to brown and purple.

A thin surface of steel can be given to iron by a process which is called "case-hardening." The article desired having been made of iron, it is heated to a bright red heat, and while in that condition some yellow prussiate of potash (ferrocyanide of potassium, $K_2F_eCN_3$) reduced to a powder is sprinkled over it. Another plan is to coat the iron while cool with a thin paste made of the same salt mixed with a little clay, and when dry raise the metal to a white heat, and then when it has cooled down again to a red heat, plunge it in cold water. The prussiate of potash is decomposed in either case by the heat, and the carbon (assisted perhaps by the presence of the nitrogen) enters into combination with the metal, converting its surface into steel. Keys and many other articles are often case-hardened in this way. The nitrogen contained in the cyanogen seems to play an important part in effecting the conversion; and some metallurgists even contend that it is a necessary ingredient of all steel; though if such be the case the quantity is so small as not to be estimated with certainty by analysis. Iron may be heated in the presence of carbon in a vessel from which all the air is excluded, without steel being produced; nor will iron be converted into steel by heating it in an atmosphere of the hydrocarbons alone; both these facts seem to favour the supporters of the nitrogen theory. Case-hardening will also result if iron be heated in the presence of horn shavings, old leather, or any other such nitrogenous compound.

A steel casting may also be made upon a foundation of wrought iron. For this purpose the iron must be raised to a welding heat, and the surface dusted over with a little borax to prevent oxidation, and while at that temperature the molten steel must be poured upon it. On cooling they will be found to have welded together, and the union is perfected by the usual processes of hammering and rolling. Under proper management the join will be so complete that the two portions cannot be again separated.

Having now described the ordinary mode of preparing and dealing with the finer qualities of steel, it remains to consider some processes by which a lower quality may be produced in much larger quantity, and at a more moderate price; and also to speak of some of the uses to which this steel is now being put on an extensive scale.

In this manufacture pig metal or old iron is used, and most of the plans adopted are actually only modifications of that of puddling iron.

In making the steel direct from pig iron, a puddling furnace similar to the ordinary one described in page 273 may be used; and the principal difference in the working will consist in always moderating the heat by the damper, so that it shall never exceed the welding-point of steel; in increasing the amount of cinder by the addition to it of some clay to retard the escape of the carbon; and in introducing the charge of pig iron in two instalments, about one-eighth being added after the other seven-eighths have begun to melt. The result of these variations is that the action is much less violent than in puddling iron, and a sufficient quantity of carbon is left in combination with the metal to convert it into steel. A little of the black oxide of manganese is also thrown into the furnace, the beneficial effect of which in removing other impurities has already been

described. The tensile strength of steel thus made has been found to be rather more than double that of puddled bar iron.

A steel not very rich in carbon, but still sufficiently so to impart to it its distinctive qualities, may be prepared from good grey pig iron, by the ordinary process of puddling; care, however, being taken to keep the furnace throughout the whole operation at a lower temperature than that adopted in the iron manufacture.

It will be seen that in both these cases it is pig iron, and not refined metal—still less malleable iron—which is made use of. The reason of this will be sufficiently evident. In every step of the iron manufacture the metal loses more and more of its carbon, while at the same time it is being freed from other impurities, whereas the preservation of a certain per-centage of carbon is the chief care of the steel maker. It is therefore important that only the best quality of pig should be used, or the steel when made may be found to contain so much sulphur, phosphorus, and silicon as to render it almost valueless.

In order to obviate this objection old iron has been turned to account; but such malleable iron, though very free from the objectionable ingredients, contains very little carbon either, and it has, therefore, to be re-carburised by being melted in a blast-furnace at a very high temperature in the presence of coke. The metal resulting from this operation has taken up a considerable amount of carbon from the fuel, and is then eminently suitable for the manufacture of puddled steel by the direct process just described.

Another modification is but the carrying out of a very old theory, which, however, was found almost impracticable until Messrs. Siemens' regenerative gas furnace was introduced. It consists of melting wrought iron in a bath of liquid pig iron, by which a fair average quality of the resulting compound will be obtained; while by duly proportioning the two sorts, and adding to it some manganiferous pig, a sufficient proportion of carbon will be supplied to convert the whole mass into steel. The importance of the gas furnace lies in the necessity of employing an intense heat to melt the malleable iron; and of having a non-oxidising flame, for otherwise the carbon would be converted into carbonic oxide, as in puddling, and would be lost.

MUSEUMS: THEIR CONSTRUCTION, ARRANGEMENT, AND MANAGEMENT.

BY SAMUEL HIGHLEY, F.G.S., ETC.

II.—THE AIM OF INTERNATIONAL, NATIONAL, LOCAL, AND SCHOOL MUSEUMS.

National Museums.—The aim of a national museum should be, to include the most perfect collections a nation's wealth can attain, to illustrate natural philosophy, natural history, geography, human history, applied science and art arranged under the superintendence of the leading authorities of the day in each department, so as to be a standard of reference in every branch of knowledge that can be illustrated.

The beau-ideal of a national museum would be, where all such departments could be included in one vast building, erected in the principal city of the country, in connection with a national college, that the collections might be fully utilised, by being employed in teaching the highest branches of science and art.

Through the manner in which collections to illustrate various departments of science and art spring up piecemeal, rather than as the result of one vast and well-organised scheme, the divided party interests thereby established, and the local difficulties of securing space sufficient on a good and convenient site in the great cities of the world, it is seldom we can expect to find this idea of a national museum carried out in its completeness, and we must rest content as now to see our collections arranged in separate buildings, often placed miles apart, under divided authority, and in some cases with antagonistic aims. Could all a nation's science and art treasures be brought together under one roof, or in closely connected buildings, how much better, and with what economy of space and material, might they be arranged to show the inter-relations of the various sciences, and science with art.

In such a museum the gallery of Natural Philosophy ought to include diagrams, models, specimens, and apparatus to illustrate the laws of the universe and the technical details of construction of the philosophical instruments employed in their study and demonstration, so as to be alike serviceable to the professor, the student, and the mechanic. The gallery of natural history should embrace a complete series to fully illustrate the principles and terminology of mineralogy, botany, zoology, and geology, including astronomy in its physical aspects, as an introduction to systematic natural history.

The systematic collection should include every known species and variety of mineral with models of its characteristic crystal forms *en suite*, together with suitable illustrations of any *specific* chemical, physical, or morphological character. Laboratory products should be treated as mineral species, and find a place in the systematic series; for where exists the difference between the crystallogenic forces that produce the *cyanose* of the mine, and the sulphate of copper of the laboratory? How should we know that sulphur is dimorphous without resort to the crucible? or that iodides, bromides, chlorides, and fluorides form isomorphous groups, if we were not to take cognisance of laboratory products? As well might modern botanists and zoologists ignore the extinct species of former epochs wherewith they now fill up many a gap in their classification, and show how the system of Nature forms one connected chain, though here and there a link may be lost to us.

As an appendix to "*Homogenia*," which embraces *mineral species* proper, should be added "*Heterogenia*," the division that includes such bodies as are described in works on petrology, some being of definite chemical composition, but of composite structure, as coal, bergmehl, etc.; mechanical mixtures of chemical bodies, though of apparent homogeneous aspect, as obsidian; and erupted, sedimentary, metamorphosed, conglomerated aggregates of mineral matter, comprising *rocks* proper.

Next in the systematic collection should be arranged every known recent and fossil species and variety of plant, either preserved or represented by model, with suitable illustrations of any *specific* or histological characteristics, deviation from type, etc., after the method adopted at Kew, etc. Then should follow every known species and variety of animal, showing the external form, either by preserved specimen or by model, its generative, nutritive, respiratory, circulatory, nervous system, organs of sense, and in the vertebrates the skeleton, together with any *specific* or histological characteristics, according to the elaborate manner suggested by Professor Owen in this country, and by Professor Agassiz in America in their Government reports on their respective national zoological collections. Although every known specimen and variety should find a place in a national museum, it does not follow that it should be "displayed" to public view, as will be shown when I come to speak of the arrangement of national collections, so that the space required is not so great as might at first sight be supposed. Immediately following on the systematic mineralogical, botanical, and zoological collections or classified series, should be arranged the geological specimens illustrative of mineral characteristics of the earth's crust, and the distribution of vegetable and animal life in time, and the astronomical aspects of our earth in relation to other planets, etc., in space.

The Geographical Gallery should embrace astronomical models and diagrams, to show the position of our earth in relation to other planets, etc., in space, and to their physical characteristics; relief maps and globes on the largest scale, to give the best attainable notion of the distribution of land and water and surface aspect of our earth; scenic groups, showing the characteristic plants, animals, and ethnology of the great divisions of the globe and of its oceanic depths—in fact, "aspects of Nature." Then illustrations of the geographical distribution and range of particular species of plants and animals, and of the representative species in different parts of the globe. Finally, the detailed geographical features of all important places; their rocks, minerals, plants, animals, inhabitants, manufactures, manners and customs, etc. In fact, the Geographical Gallery should form an illustrated gazetteer of the highest order, wherein real and authentic specimens of minerals, plants, and animals, or life-like models of the natives and their surroundings, should convey to the eye the gist of geographical science and the natural history of our earth.

The gallery of Economic Natural History should show the purposes to which minerals, plants, and animals are applied to the wants of the human race, comparative samples of the same

products from different sources of supply, and every detail that can be illustrated by specimens or other appliances explanatory of technology and commerce in relation to Nature's products.

The gallery of Human History should illustrate the development of civilisation from the earliest epochs of which we gain glimpses through the studies of the geologist and archæologist, on to the times when records began to aid historical research, up to the present day. Such a collection should illustrate the rise and fall of nations; the geographical march of civilisation; the buildings that have characterised nations and epochs; the arms, armour, and modes of attack and defence of the peoples of the earth, as illustrations of progress in the art of war on land and sea; the manners and customs of nations in their historical aspect, and the history of mechanical inventions that have exercised civilising influences on mankind; the development of art, from the crude attempts at decoration of the savage up to the most sublime efforts of the world's greatest artists and sculptors, as displayed in the Gallery of Art. The idea of such a national museum may appear at first sight little better than a Utopian dream; but as regards our own country, were the collections of the British Museum, Kew Museum, School of Mines, South Kensington Museum, India Museum, the Tower Armouries, Arsenal Museum, National Gallery, etc., brought together under united management, there would be ample material for laying the basis of a national museum established on such a scheme, and the advantage to professors, students, and the public would be undeniable.

Though we have ample material for a national museum of this magnitude, as yet we have not space sufficient wherein to display our artistic, scientific, and antiquarian treasures. The British Museum may to a great extent be regarded as a bonded warehouse where specimens are stowed away, unpacked or undisplayed, till the public has paid duty on them in the shape of erecting more extensive galleries wherein they can be arranged and exhibited to national advantage. The natural history collections at the British Museum are to be removed to a new building at South Kensington, in close proximity to the Arts' Museum. If the School of Mines and the Kew and British Museums were united under one department, and a geographical series added, we should have the scientific collections under one roof and undivided management. The British Museum might then be devoted to the illustration of human history; such collections as the Tower armouries, etc., being removed there to complete the series, and bring such objects under one head and undivided management.

Local and School Museums.—While national museums should illustrate the departments of science, art, and history in detail, local museums should supply an epitome of knowledge, together with the detailed natural history and archæology of the surrounding districts. In such museums the natural history series can only be illustrated by "*typical species*," and the general principles of chemistry and physic by the mineralogical illustrations, as will be shown hereafter. The aim of school museums should be to furnish a well-selected and progressive series of illustrations that should serve as an index to the broad principles of knowledge. In such museums the natural history series can only be illustrated by "*typical forms*," and "aspects of vegetable and animal life," to convey a sufficient idea of the modifications of form. In carrying out this aim, not a specimen more than is necessary should be employed, as economy in space and purse is of primary consideration.

PRACTICAL APPLICATION OF THE FINE ARTS.—V.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

DOMESTIC GLASS.

There are many opportunities for the use of painted glass in domestic architecture which are not fully appreciated. In fact, the architect is apt to forget the position which he ought by right to take in regard to the other art. He is usually oblivious of the fact that in the minds of the first—and, we may also say without disparagement to other styles, the greatest—architects of Europe he was the chief artist who should make all other arts subservient to his own end and views. Now that artists of all kinds are becoming bolder, and are claiming each for his special calling a place in the great harmony of taste, and that we are not afraid either to imitate our ancestors of the best times or to adapt their styles and their work to the exigencies of modern requirements, there is no reason why the glass-painter should not claim a position not only in the church and cathedral, not only in the civic town-hall and the baronial manor-house, but also in the country rectory and the modest town dwelling-house. It is fitting, of course, that the guildhall of a great city should commemorate on its walls and in its windows such events of local history as are connected with the rise and advancement of its liberties and its commerce. Many a Continental Hôtel de Ville thus tells a tale of sturdy striving after independence or of successful enterprise, which otherwise would have fallen into oblivion. The glass with its rich tone of deep colouring matches with the varied architecture of Gothic or of Renaissance.

And the nineteenth century, breaking out again into a desire for architectural display and feeling, after a style which may

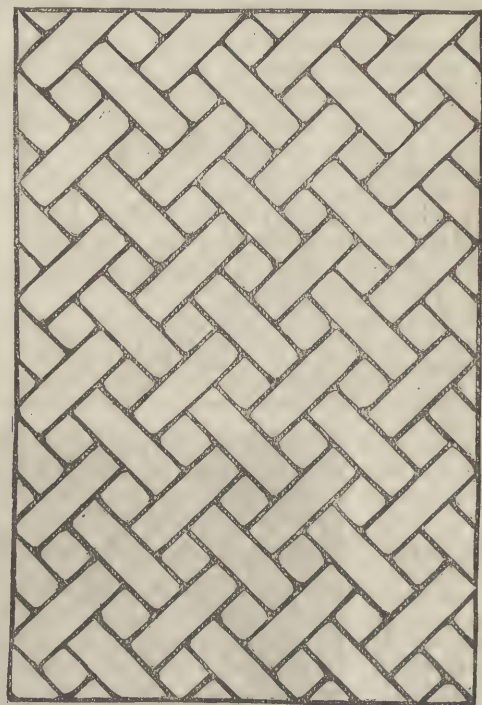


Fig. 3.

hereafter accommodate itself to the wants of a time of mixed thought and progress, has not been behindhand in seizing upon many of the arts borrowed from the days of former builders, in trying to catch the fire of old enthusiasm, and in handing down to its successors a heritage from which the latter may start on a new quest after the beautiful and the great. In this search the art of glass-painting is one that must not be despised; and in order to adapt it to the requirements of greater works it must be utilised in those of minor importance. The homes of our aristocracy, again, whether it be of those who through long lines of distinguished ancestors have handed down titles of nobility to their descendants, or those minor magnates who have lived rather in the hearts of their dependents and in the eyes of their envious neighbours, form fitting resting-places for those heraldic devices which tell long tales of genealogical development and of unstained honour. Close upon the hall the country rectory raises its less pretentious head; but as the parson in England is usually a central point from which not only a higher civilisation is spread around, and a more liberal education permeating all the classes of society, but also a more refined taste combats with the extravagant luxury of the growing plutocracy and impresses its lessons upon the rising race, so in his house we expect to find the elements of a refined taste combined with strict economy. In the rectory, then, we may expect to see a little piece of old twelfth-century glass well leaded and framed,

and now and then a modern window carefully chosen both with regard to subject and expense. But it is not alone in these that we hope to see our art extended. The ordinary professional man's house built in the street of a busy town naturally abuts upon many an object that is not altogether pleasing to the eye. Light is required—the denser the population the more does it become a necessity and the greater is the difficulty in acquiring it, but the outlooks are not agreeable; we must have windows, but we do not care to look through them; we must look into the streets, but we do not wish that every passer-by should return the stare and become familiar with all the doings of our little home; we must light our staircases with openings that front upon our neighbours' premises. In order to keep out the unpleasing sights and the unwelcome eyes, we resort to the dull, colourless, light-destroying blinds, or we insert the so-called ground-glass, either plain or else ornamented (save the mark!) with a pattern of stars or flowers. How much more pleasure might be derived from the contemplation of one of the many species of coloured windows than from either of these dull, lifeless, insipid transparencies! Blinds fully deserve their name, but a well-arranged window of slightly coloured glass, with a pattern not too formal, rests the eye, leads it on from one portion to another, so that it is not fatigued, while at the same time it is employed. Of course, care must be taken with choice of designs and also in the carrying out of those designs. Staircase and library each may have their appropriate style. Three great requisites for stained glass windows — nearly luminous transparency, good composition, and brilliant colouring without confusion—may frequently be more effectively procured, and may be obtained at the cost of less labour in such windows as those we are now describing than in the more elaborate designs for public buildings.

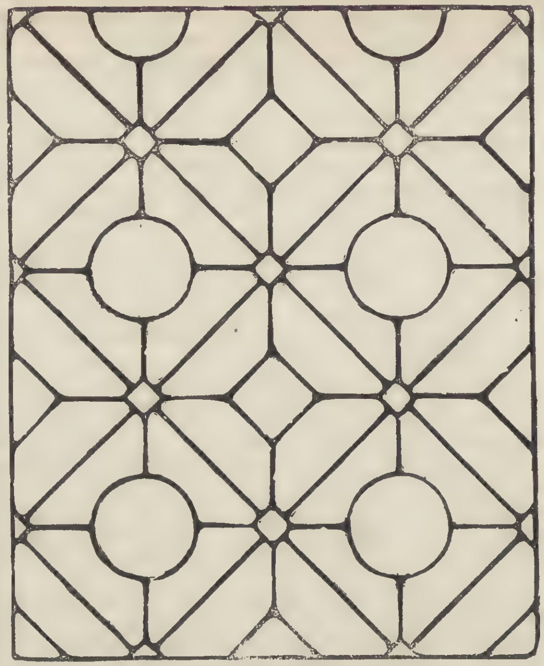


Fig. 5.

Luminous transparency may be obtained by careful attention to the glass employed. In very many cases this may consist in great part of what is technically called white glass, that is, glass with only a slight tinge of some plain colour, various tones of green inclining to blue, sometimes with a tinge of brown, but all more or less rendered unsuitable for looking through at what is beyond by air-bubbles and roughnesses of surface. The choice of colour in this glass is highly important, and it should be made in reference to the remainder of the pattern. In many cases the complementary colour to the bright and deep colouring of the other parts will throw the latter into high relief. But when a complementary colour is chosen, it should be remembered that the lighter colour must not outweigh by its quantity the depth of tone of the smaller pieces. For instance, if small quarrells of ruby glass are inserted in a groundwork of a so-called white glass which really possesses a greenish tinge, the green must be deadened (in colour not in transparency) in proportion as it is desired to make the red look bright. At the same time the whole amount of green spread throughout the entire groundwork of white glass, supposing it were collected in a small deep-coloured patch, must not exceed the total amount of ruby. The weighing of these opposing colours requires considerable skill, judgment, and experience, in order to arrive at those pleasing effects which mark the good colourist. When deeper colours form the staple of the design, then it is also necessary to see that all these deeper colours harmonise. The glass of one maker frequently will not run well with that of another; and even of glass made by the same man it is not always easy to obtain that which from depth of tone and calibre will give the most pleasing effect.

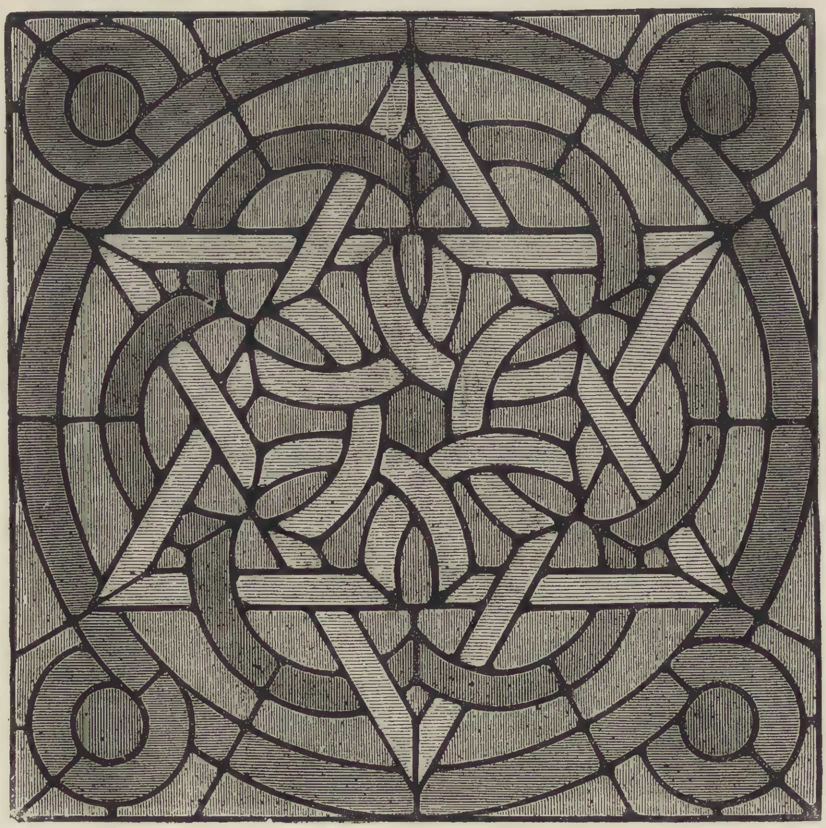


Fig. 7.

Good composition, of course, is a necessity; and it is more rare than people imagine to find designs in which the forms are pleasing to the educated eye. To a certain extent the principal forms in the patterns of which we have been speaking must be geo-

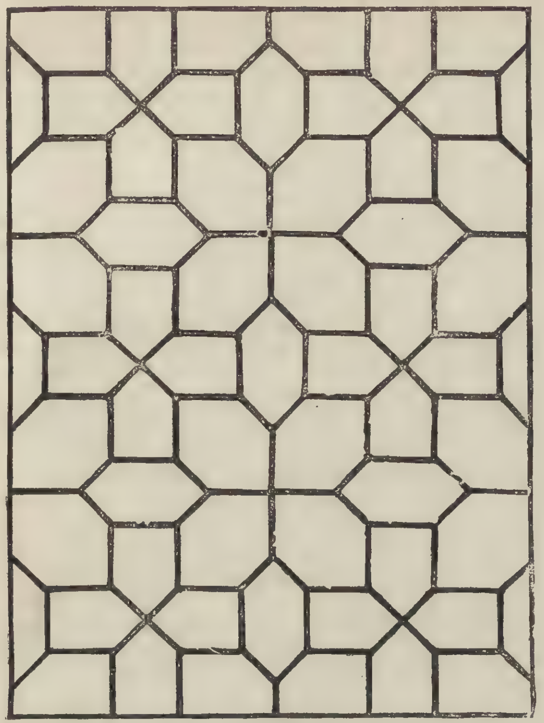


Fig. 4.

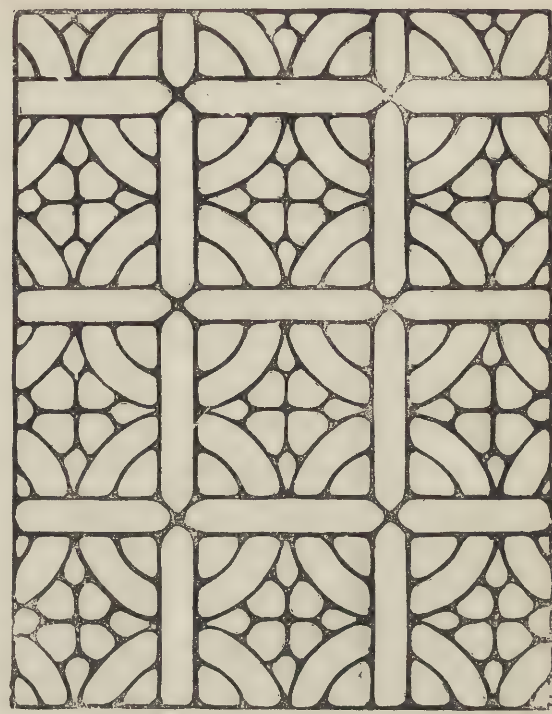


Fig. 8.

Fig. 6.

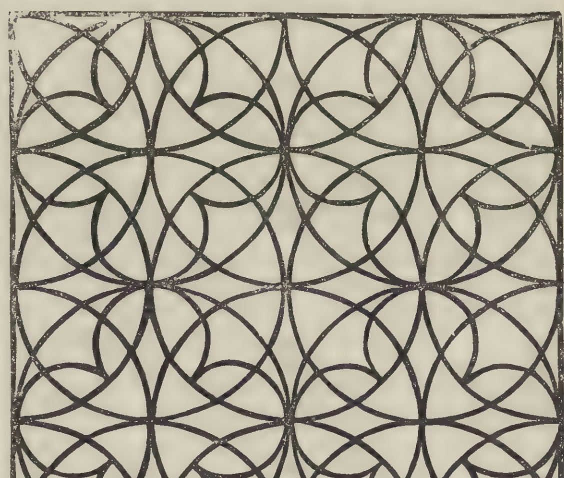


Fig. 9.

metrical, and they are confined to only a few geometrical figures. Diamond-shaped panes, combined with oblongs of various proportions, must necessarily form the staple of the shapes within which the patterns must be designed. But having such a large proportion of straight lines naturally within these boundaries, we shall look for curved lines of various characters. Thus we shall employ arabesques, grotesque shapes, and idealised forms of natural objects. Of course, it must always be remembered that these forms can only be carried out in brown or some similar tint, and that the only colour that can be added is the yellow stain, but these combined with shapes into which the glass is cut offer a considerable amount of variety at the command of a skilful artist. Brilliant colouring without confusion is only to be obtained by attention to the laws of colour, which, of course, are the same in this case as in all others.

Heraldic devices are frequently appropriate and, at the same time, striking and pleasing objects; they require, moreover, but a slight amount of shading, and give opportunities for the introduction of quaint and antique lettering in mottoes, which in this case may well be made so far difficult of decipherment as to employ the ingenuity of the beholder without taxing his energies too far. The heraldic rule of never laying metal upon metal, nor colour upon colour, will generally prevent any very unpleasant contrasts. The metals here spoken of are gold and silver, represented of course by yellow and white; whereas the colours consist of red (a deep ruby), blue, black, green, and occasionally purple and orange. In giving heraldic designs, however, either some knowledge of heraldry is required, or very strict attention must be paid in copying forms and colours from some given examples. It is so frequently the case that antiquarians, genealogists, and country gentlemen have some acquaintance with the quaint laws and devices of this ancient art, that any attempt at letting the imagination run wild in such matters is sure to end at least as unfortunately as it did in the case of the author of "Ivanhoe," who, in spite of his otherwise extensive antiquarian knowledge, got into sore disgrace with the technical heralds for his blazon of the shield of the Disinherited Knight.

We hope that the hints and illustrations given in these papers may induce many to attempt to decorate their houses with this pleasing style of ornament. We have not aimed at making glass-painters out of those who have never taken such work in hand; but we hope to induce some to try those parts of the art which are more within the scope of the amateur, and give others a view of the main difficulties that hedge in the art as at present practised. We have known of cases in which ladies have furnished their own designs, obtained the glass cut in accordance with the drawings from those whose business obliges them to keep a large stock, painted the glass themselves with a boldness and vigour that professional artists seem afraid to employ, and ended by securing exceedingly handsome as well as interesting ornaments for their houses. In some cases a story has been illustrated by a series of designs, each filling the common oblong pane in a staircase window, the nine or twelve panes forming a sufficient number to carry out the whole tale.

In a series of this kind, the grisaille style, only in brown with the yellow stain, will be found most manageable.

We trust that the taste for stained glass is on the increase, and that before long it will be rare to find a house with any pretensions to beauty and ornament without some amount of this simple, pleasing, and useful decoration.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XX.—M. DE REAUMUR.

BY JAMES GRANT.

René Antoine Ferchault de Reaumur, the discoverer of a mode of casting iron into steel, of making coloured porcelain, colouring turquoises, and making artificial pearls, etc., was born at Rochelle, in 1683, during that which has aptly been termed the Augustan age of France, when every department produced its illustrious men—which gave to arms such leaders as Turenne and Condé; to literature, Racine, Corneille, and Molière; and to oratory Bossuet and Fénelon. He learned grammar in his native city, and studied philosophy in the college of the Jesuits at Poictiers, whence, in 1699, he went to Bourges, where he studied civil law. He went to Paris in 1703, and gave his entire time to natural philosophy and mathematics. When only four-and-twenty, in 1708, he was chosen a member of the Royal Academy of Sciences, and during that year and the following he described a general method of ascertaining all curves described by the extremity of a straight line, the other end of which is moved round a given curve, and by lines which fall upon a given curve under a certain angle greater or less than a right angle.

In the year 1710 he read observations on the formation of shells, proving that they grow, not like the other parts of the animal's body, by expansion, but by the external addition of new parts. He also illustrated the cause of the variety in colour, figure, and magnitude, by which one shell is distinguished from another. In the course of these investigations, he discovered that upon the common snail there grows a singular little parasite, which burrows into its body and never leaves it. M. Bon, the first President of the Chamber of Accounts at Montpellier, having shown in a paper "that the webs made by spiders to deposit their eggs in might be spun into a kind of silk applicable to useful purposes, but that it was still necessary to determine whether spiders could be bred in sufficient number without an expense too great for the undertaking to bear," Reaumur thereupon published his "Natural History of Cobwebs," proving that Bon's discovery was merely a matter of curiosity, and of no value whatever to the commercial world.

In the course of his inquiries into those organs and materials by which so many marine animals adhere to solid bodies, he discovered a fish different from that which furnished the ancients with their Tyrian dye, and which has the same property in a much greater degree. Upon the sides of this fish are small grains like those of a hard roe, which, on being broken, yield at first a fine yellow colour, which ere long, on exposure to the air, changes to a beautiful purple tint.

It was about this time that he made so many experiments to discover whether the strength of a cord was greater or less than the sum of the threads composing it. Hitherto it had been supposed that its strength was greater, but M. de Reaumur's experiments proved it to be less. Thus it necessarily follows that the less a cord differs from an assemblage of parallel threads, or the less it is twisted, the better; for "that mode of uniting various threads into a cord is undoubtedly the best which causes the tension of the threads to be equal in whatever direction the cord is strained, and this consideration is sufficient to render the common method of combining threads into cords by twisting preferable to all others."

Reaumur was the first who dissipated the old popular error that when crawfish, crabs, or lobsters lost a claw, Nature produced another in its stead, by tracing the asserted reproduction through all its circumstances, which are even more singular than the thing itself. This discovery was simply a matter of curiosity; but others that followed were of use to society.

An idea had previously prevailed that the turquoise stone was found only on the mountains of Nishapore, in Khorassan, but he discovered a mine of them in Languedoc. He had, however, to ascertain the exact degree of heat necessary to colour them. He proved, also, that the turquoise itself is only a fossil bone petrified, coloured by a metallic solution, which is spread by the application of heat, and for the production of this heat he invented a furnace; so the turquoises of France, in size and beauty, are quite equal to those of Persia. His next discovery was the secret of making artificial pearls, and the substance necessary to give them purity of colour, which he drew from a small river-fish called the *ablette*, or blay. At the same time he published a dissertation upon the true pearl, which he asserted to be a morbid concretion in the body of the animal. Soon after this appeared his history of the auriferous rivers of France, with a mode for separating the grains of gold from the sand. Among other memoirs, he published one concerning that vast bank of fossil shells which in Touraine is dug for manure; another proving that flints are only possessed of a more stony juice, "or, if the expression may be permitted, more stonified than other stones, though less than rock crystal;" another upon the nostoch, a curious fungus, which appears only after heavy summer rain; upon the light of dails, fish that shine in the dark, but only until they grow stale; and, lastly, "upon the facility with which iron and steel become magnetic by percussion."

In 1722, when the art of converting forged or bar iron into steel was totally unknown in France, he published a work on that subject, together with the art of rendering cast iron ductile. Having discovered that steel differed from iron only in having more sulphur and salt among its component parts, he conceived that cast iron differed from forged iron only by having still more sulphur and salt than steel; it was steel with an excess of its specific difference from forged iron. By extracting this excess, he produced a variety of utensils in cast metal which were as easily wrought as the forged iron, and cost but half the money. For the discovery of this secret—though the manufactory proved eventually a failure in France—Philip, Duke of Orleans, then Regent of France, settled upon him a yearly pension of 12,000 livres, and at his request it was settled upon the Academy after his death, "to be applied for defraying the expenses of future attempts to improve the arts."

His next discovery was the secret of making tin as it was made in Germany; and after he had instructed a sufficient number of his countrymen in that useful art, France ceased to import tin from abroad.

Next to this came an improvement on the art of making porcelain, which had hitherto been manufactured at Dresden and Saxony only, at least in Europe, to which the art had been originally brought from China by the Portuguese, though no less a man than Scaliger asserts that it was known to the Romans.

A few simple experiments upon fragments of glass, porcelain, and pottery convinced him that china-ware was nothing more than a demi-vitrification, which may be obtained either by exposing vitrifiable matter to the action of the fire, and withdrawing it before it is perfectly vitrified, or by making a paste of two substances, one of which is vitrifiable and the other not. He soon discovered by which of these methods the porcelain of the Chinese was made. "Nothing more was necessary than to urge it with a strong fire: if it consisted wholly of a vitrifiable matter half vitrified, it would be converted into glass; if of the two substances, one of which was not vitrifiable, it would come out of the furnace the same as it went in." This experiment being made, the porcelain of China suffered no alteration; but that of Europe was changed into glass.

His next attempt was to discover what these two component parts of the Oriental porcelain were, and whether France could produce them. In all this he was successful: both kaoline and petuntse were found in abundance and perfection at home, but in quarries of great depth.

Reaumur was the first who reduced thermometers to a common standard, so that the degree of cold indicated by a thermometer in one place might be compared with that indicated by a similar instrument in another, prescribing rules by which two thermometers might be constructed that would exactly coincide with each other through all the variations of heat and cold, fixing the middle term, or zero, of his division of the tube at the point to which the fluid rises when the bulb is plunged in water that is beginning to freeze. He also prescribed a method for regulating the divisions in proportion to the quantity of fluid, and not by the aliquot parts of the length of the tube; and he directed how spirits of wine might be reduced to one certain degree of dilatability.

Thermometers constructed upon these principles were called "Reaumur's thermometers," and soon took the place of all others then known.

His next inventions were the somewhat singular ones of not only preserving but hatching eggs. The latter art had long been known to the Egyptians, but was a secret to the rest of the world. He found out and fully detailed the various ways of producing an artificial warmth, by means of which chickens might be hatched before fires or in dunghills; and he invented long cages in which the callow fledglings were preserved in this first state, with fur cases to creep under in lieu of the hen's wings or bosom, prescribing the food for them in various stages, and where it was to be procured. He also discovered that eggs might be kept fresh and fit for incubation for many years by simply dipping the shells in varnish, oil, or grease, to stop the pores; and thus birds from the most distant parts of the world could be progagated in others. And it was while occupied with these useful discoveries that he was gradually proceeding with his "Memoires pour servir à l'Histoire des Insectes," the first volume of which appeared at Paris in 1734, and the five succeeding volumes between that time and 1742. Volume I. contains the history of caterpillars, which he divides into seven classes, each distinct in character; he details the modes of their subsistence under the caterpillar form, as well as in the state of chrysalis, the changes they undergo, their food, and method of spinning their webs. Volume II. describes them in their third state, that of butterflies, with many curious particulars relating to their figures, tints, the beautiful dust with which they are powdered, their mode of coupling and laying their eggs. Volume III. contains the history of moths, not only of those which are so destructive to woollen stuffs and furniture, but those which live on the leaves of trees and in the water. This volume also contains an account of the vine-fretter, an insect as destructive in gardens as the moth is in furniture, with an account of the worm that devours them, and the galls produced upon trees by the puncture of some insect which makes its habitation in the bark. Volume IV. contains the history of those gall-nuts or protuberances, which, though galls in appearance, he asserts to be really insects, but condemned by Nature to remain for ever fixed upon the branches of trees. Then follows the history of the gnat or gad-fly. Volume V. treats of four-winged bees, and shows that they are not the only fly which makes honey, as many species of the same genus live separate or in little communities. Volume VI. contains a description of the wasp, the pismire, the horse-stinger, and ephemeron, a singular insect which, after living three years as a fish, lives as a fly for only a single day, during which it couples, deposits its eggs in the water, and then dies.

Among anatomists it had long been a question whether digestion is performed by solution or trituration; but Reaumur, by many dissections and experiments, discovered that it was the result of the former; and his observations on this subject, communicated to the Society in 1756, were the last he ever penned, as he died of an injury received on his head by a fall at Bermondière, in the Main (on an estate which had been bequeathed to him by a friend), on the 17th of October, 1758.

M. de Reaumur, who had attained his seventy-fifth year, was a man of the most patient research and investigation, of ingenuity and learning; and throughout his useful life his heart had ever been inspired by the warmest benevolence, and the highest emotions of honour, liberality, and religion.

OBJECT DRAWING.—XI.

In Fig. 63 we have a view of the same object when turned so that the steps are parallel to the plane of the picture.

We will first consider the elementary form on which the present subject is based. In Fig. 61 a view of the compound block, made up of nine oblong blocks, has been given. In the present case, however, the object is placed so that the ends are at right angles, instead of being parallel to the plane of the picture.

Draw, in the first place, the rectangle *a b c d*, which represents the front of the whole block, the length in the model being twice the height. From *a*, *b*, and *c* draw lines to the point of sight. Draw the back perpendicular, *e f*, and the distant horizontal, *f g*, completing the general view of the block. Now divide *a b* into three equal parts, by the points *h*, *i*, and from these draw lines to the point of sight. Between *a* and *e* set off *j* and *k*, thus dividing that line into three parts; but these are to decrease gradually as they recede from the foreground. In perspective, this (as will be remembered by those who have studied that subject) would be done by setting off *a h*, *h i* on the picture-line, and drawing lines to the point of distance, cutting *a e* in the required points. In the present case the matter must be left to the judgment of such as have not studied the grammar, and it is hoped that the often-recurring question, "How am I to know the width?" etc., to which in model drawing no true answer can be given, will lead all who wish to draw properly and scientifically to take up the grammar of drawing on which all correct delineation must be based—object drawing being distinctly a free-hand application of the scientific principles.

Having, then, marked the points, draw perpendiculars from them passing through the lines *h* and *i* drawn to the point of sight; the quadrilateral *a b f e* will thus be divided into nine four-sided figures, which will respectively represent the blocks shown in the previous view. Horizontal lines drawn from *h*, etc., will complete the view of the block made up of nine oblong solids.

Now it will be remembered that, from this composite block, three of the smaller solids are to be removed in order to transform the mere oblong into a flight of three steps; this having been done, the drawing can be proceeded with.

Draw the line $h\ r$, then the rectangle $a\ h\ r\ d$ will be the front of the step in the immediate foreground. From r draw a line to the point of sight, and from l draw a line to meet this in s; thus completing the view of the first step. At l erect a perpendicular, $l\ m$, which will represent the height of the second step, $l\ m$. At s erect a perpendicular, and draw $m\ t$. From t equal to $d\ r$ or $a\ h$. Draw the horizontal $w'\ x'$, then the rectangle $w\ w'\ x'\ x$ will be equal to $a\ h\ r\ d$, the front one of the blocks which forms the lintel of the doorway resting on the jambs. Produce the perpendicular $u\ v$. Draw lines from w and w' to the point of sight. These cutting the perpendicular $u\ v$, will give the points y and z.

Draw a perpendicular at o, and draw lines to the point of sight from $x'\ x$, cutting the perpendicular in z' and y'. The horizontals $z\ z'$ and $y\ y'$ will then complete the rectangle representing the front of the jamb.

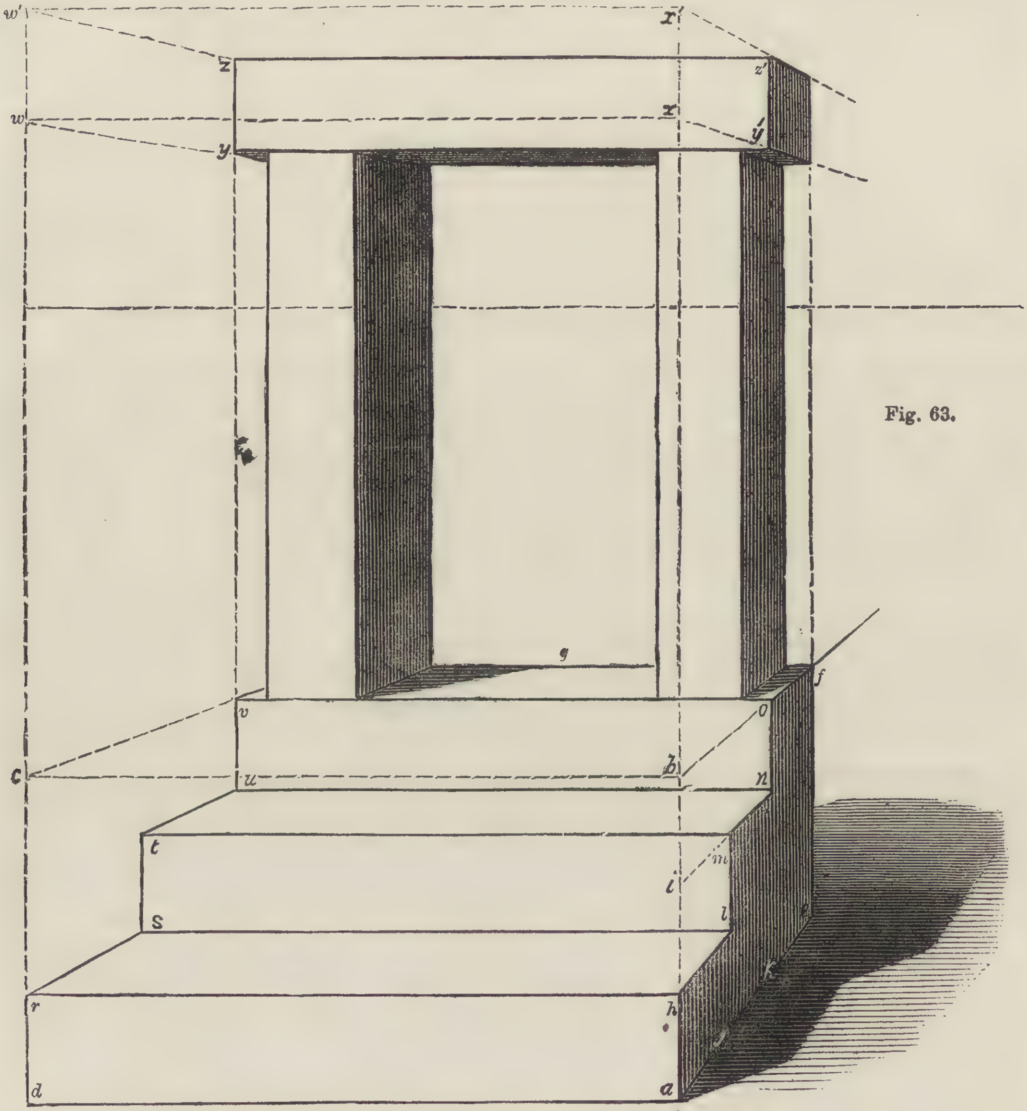


Fig. 63.

draw a line to the point of sight, meeting a horizontal drawn from n in u. This will give the view of the second step.

Draw $n\ o$ and $u\ v$. Join $o\ v$ by a horizontal line. Draw lines to the point of sight from o and v, and the whole block is then completed by the horizontal line already drawn from the distant angle. Now, on the line $o\ v$, erect perpendiculars for the front of the jambs of the doorway, and proceed to find their perspective height. It will be remembered that the blocks now used as the jambs at first formed parts of the original block; their real height, then, is equal to the length $a\ d$. This height will, of course, be diminished by their distance from the foreground.

To find the apparent height, therefore, erect at c and b the perpendiculars $b\ x$, $c\ w$, and draw $w\ x$.

Produce the perpendiculars beyond w and x to w' and x',

Now, from the bottom of the right-hand perpendicular of the jambs, draw lines to the point of sight; and these cutting the back horizontal of the block will give the positions for the distant perpendiculars forming the sides of the jambs, which are to be terminated by lines drawn from the tops of the left and right perpendiculars of the jambs.

The perpendicular forming the distant edge of the block of steps will terminate these and give the end of the jamb, from the lower point of which a horizontal will complete the soffit.

The shading, as in the last case, is extremely simple, the cast shadow on the ground following the form of the steps.

PATTERNS FOR MAKING DRAWING MODELS.

It has already been stated that a set of models has been

specially designed to carry out the system laid down in these lessons. These, although of a size adapted for class teaching, are not too cumbrous for private study.

Still, with the view of promoting that self-help which forms so great an element of success in life, the following set of patterns are introduced; by these the principal models may be made in cardboard, and thus a useful set for home use will be acquired. The cardboard should be sufficiently strong not to bulge out on the sides, but at the same time it must not be too thick, in which case it would not give sharp edges at the angles.

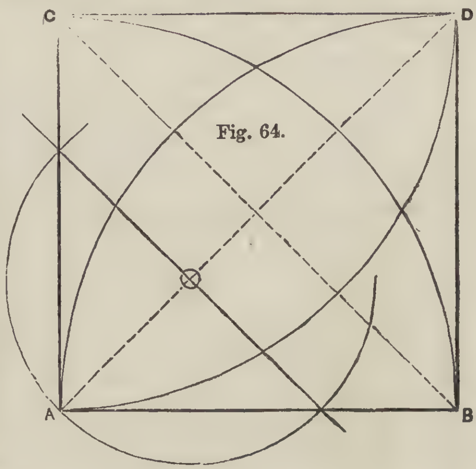


Fig. 64.

Perfect skill in the construction of these models must depend on the student's knowledge of practical geometry and development (see lessons on "Practical Geometry applied to Linear Drawing" and "Projection"); but as it is desirable that each of the courses should be as complete in itself as possible, the simplest method of constructing the figures is shown. As, however, the subjects named are of universal application, the student is strongly advised not to remain satisfied with the small amount of instruction in those branches which the limits of the present series of lessons permit, but to follow out the systematic course laid down in those referred to.

The simplest model to make, and also the first required in object drawing, is the cube; it consists of six equal squares, and therefore, to save time in referring, the geometrical method of constructing a square is here given.

Let A B be the length of the side of the required square (Fig. 64). At A draw the perpendicular A C. Make the perpendicular A C equal to A B. This may be done by placing the steel point of the compass in A, and drawing the quadrant B C with the length A B.

Now, from B and C, with the same length, draw arcs cutting each other in D.

Draw a line from C to D, and another from B to D, which will complete the square.

The student is reminded that all the angles must be *right* angles, and that all the sides must be equal. If these two conditions are fulfilled, the diagonals A D and B C will be equal.

Proceeding now to the construction of a cube, draw the square, *a b d c* (Fig. 65), and produce the sides indefinitely. From *a* set off *a e* and *e g*, equal to *a b*, and from *b* set off *b f* and *f h*. Draw *g h* and *e f*. From *c* set off *c i*, and from *d* set off *d j*. Draw *i j*.

Now, on the lines crossing these, from *a* and *c*, set off *a k* and *c l*, and draw *k l*.

On the other side, from *b*, set off *b m*, and from *d* set off *d n*. Join *m n*, which will complete the six squares.

Against the edges *a k*, *k l*, *l c*, and the corresponding lines in the opposite side, and also against *i j*, leave additional strips for a purpose to be pointed out presently.

Now the figure must be cut out. This should be done with a sharp knife, so that the edges may not be ragged. The knife should be guided by the edge (*not* the bevelled edge) of the rule.

Cut entirely through the outer lines, but only penetrate the others to about half the depth of the cardboard.

Now, inserting the point of the knife, peel off half the thickness of the strips left on the edges; the rest is to be used for the attachment of the sides.

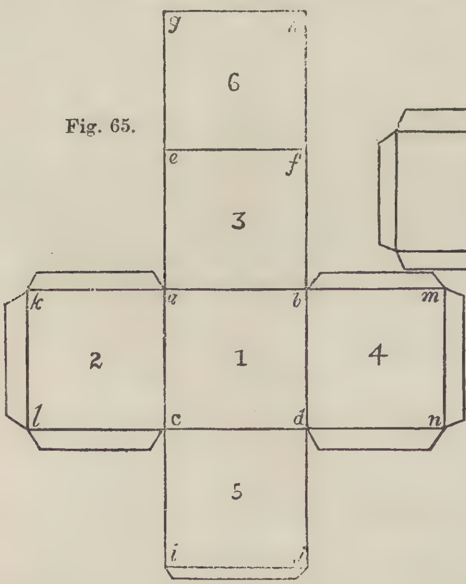
Turn the scored side of the figure downward, and turn up the sides; it will then be seen that the square No. 1 will form the base, 2, 3, 4, 5 the sides, and 6 the top of the cube, whilst the extra strips will be bent inward, and, having been deprived of half their original thickness, they will not cause the corners to appear clumsy.

Fig. 66 is an object of the same character as the cube—viz., an oblong block.

To construct this, draw a line *a b* equal to the length of the intended object, and draw *a c* and *b d* at right angles to it, and of indefinite length. Now set off from *a*, *a e*, *e f*, *f g*, and *g h*; and from *b* set off *b i*, *i j*, *j k*, and *k l*, equal to the side of the square which is to form the end of the prism. Draw lines joining these points, and the drawing will then present four equal rectangles. At each end of one of these construct a square, observing to leave the strips on the edges, as shown in the drawing, bearing in mind that the outer lines are to be cut entirely, and the others *half* through the cardboard.

It will be readily understood that the block shown in Fig. 63, in which the end is an oblong and not a square, will be constructed in a precisely similar manner.

Fig. 65.



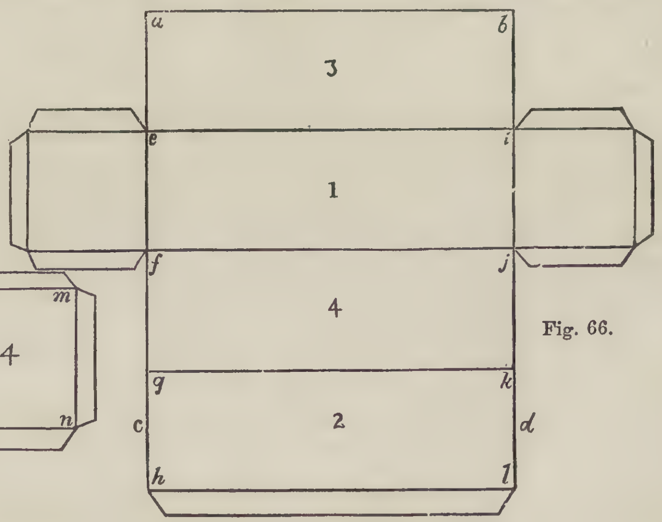


Fig. 66.

BUILDERS' QUANTITIES AND MEASUREMENTS.—I.

BY E. WYNDHAM TARN, M.A.

INTRODUCTION.

IT has been explained in the articles which have previously appeared upon "Building Construction," that before any building of importance can be erected, it is necessary that certain "drawings" should be prepared, consisting of plans, sections, elevations, and working drawings or details; these being all made upon a scale of so many feet to an inch, the builder is enabled to measure every portion of the intended structure. We propose to describe in the following articles the method which he adopts in order to be able to form an estimate of the probable cost of the work to be done, according to the style indicated by the drawings, and described in the specification. This process is called "taking out the quantities," which must be performed with the greatest possible accuracy, since a single error of measurement may make a difference of many hundreds or thousands of pounds in the amount of the estimate. It is therefore essential that the person who takes out the quantities should be thoroughly conversant with every branch of building, and the way in which work is carried out in the several trades connected therewith, as allowance has often to be made in measuring for material wasted in executing the work, so that it would not always be proper to measure the material of the exact dimensions that it appears in the building when finished.

When it is desired to obtain estimates for a work from several builders, it is usual to have a "bill of quantities" prepared by a "quantity surveyor," or one who makes that his especial business; he is appointed either by the architect under whose superintendence the building is to be erected, or by the builders themselves who are intending to compete for the job. This "bill" contains the quantity of work and material of every description that will have to be provided in carrying out the plans and specification; and by this arrangement each of the competing builders is supplied with exactly the same set of measurements, to which he has only to affix his own prices in order to form his estimate of the probable cost of the intended building. In some cases the "bill of quantities" is made to form a part of the contract entered into between the employer and the builder, so that if any work has to be executed which is found to have been omitted from the "quantities," the builder will be paid for it as an "extra," or its value added to the amount of the contract; and should it be found that any work has been provided for in the "quantities," and has not been executed in the building, it will be treated as an omission, or its value will be deducted from the amount of the contract when the job is completed. The more usual system, however, is for the employer and his architect to ignore the quantities altogether in making the contract, which is then based upon the plans and specification alone, the builder trusting to the accuracy with which the quantities have been taken out to ensure him against serious loss; or if, as is often the case, the "quantity surveyor" guarantees the accuracy of the "bill of quantities," the builder can compel him to make good any loss that he may sustain from discrepancies therein.

A contract is often entered into with a builder for the execution of the work shown upon the drawings and described in the specification, according to a "schedule of prices," which is a list of different kinds of work and material required to be provided, and resembles a bill of quantities, but the actual quantities of the several works are not stated; the builder attaches his prices per inch, foot, yard, etc., to the several items, and when the building is completed the whole of the work is measured by a surveyor, who ascertains the quantity of each kind that has been done, and prices it out at the prices previously given by the builder in his "schedule," so that the total cost of the building is only known upon its completion. A "schedule of prices" is also generally given when work has been undertaken by contract, according to which all extras and omissions have to be valued when the job is completed; these are measured up by a surveyor, and priced out by the schedule.

The system adopted by surveyors is exactly the same, whether they are measuring the work by a scale from the drawings, or by a tape and rods from the building itself; and only one standard of measurement is used in taking the dimensions—namely, the lineal foot, and its subdivision into inches. Before, however, the measurements can be brought into the form of a "bill" they have to be reduced into various forms, according to the character of the work; some kinds being taken item by item, and valued at so much apiece, when they are said to be "numbered;" others are taken by the lineal inch, foot, or yard, and are then said to be "run;" other work, again, is valued according to the area it covers, by the superficial foot, yard, etc., and is then called so many feet, yards, etc., "super.;" there are also other kinds of material which are taken by the cubic foot or yard, the three dimensions of length, breadth, and thickness being multiplied together, and the cubical contents obtained; such work is said to be "cubed."

The process of reducing all the various measurements into the several divisions of "run," "super.," "cube," is called

SQUARING DIMENSIONS.

This term properly applies only to bringing lineal dimensions into superficial or "square" measure, to which by far the greater part of all builders' measurements have to be reduced; but it has also come to be used in the more general sense of bringing all the dimensions into the various forms in which they are required for attaching the prices in the bill of quantities. When the work has to be brought into "super.," the two dimensions of length and breadth, expressed in feet and inches, are multiplied together by duodecimals, and the result is the number of "super." feet and twelfths of a foot. Suppose, for example, that the lineal dimensions are 14′ 7″ and 9′ 2½″, the process of bringing them into "super." is as follows:—

$$\begin{array}{lrrr}
 & 14 & 7 & \\
 & 9 & 2\frac{1}{2} & \\
\hline
14'\ 7'' \times 9' = & 131 & 3 & \\
14'\ 7'' \times 2'' = & 2 & 5 & 2 \\
14'\ 7'' \times \frac{1}{2}'' = & & 7 & 4 \\
\hline
 & 134 & 3 & 6
\end{array}$$

The result is 134 super. feet, 3-12ths of a foot, and 6-144ths of a foot; but the 144ths are always neglected when there are less than 6 of them, and are taken as 1-12th when there are 6 or more, so that the above would be called 134′ 4″. It must be borne in mind that the 4″ does not mean 4 inches, but 4-12ths of a square foot—that is, 48 square inches.

When the work is to be brought into "cube," the dimensions of length, breadth, and depth, expressed in feet and inches, are all multiplied together by the same method as is employed in bringing into "super.," and the result is obtained in cubic feet, 12ths, and 144ths. For example, let the given dimensions be 11′ 3″, 1′ 2″, and 11½″: first multiply 11′ 3″ by 1′ 2″, which gives super. feet, 12ths, etc., and multiply that result by 11½″; which gives cubic feet, 12ths, etc. The process is as follows:—

$$\begin{array}{lrrr}
 & 11 & 3 & \\
 & 1 & 2 & \\
\hline
11'\ 3'' \times 1'\ 0'' = & 11 & 3 & \\
11'\ 3'' \times 0'\ 2'' = & 1 & 10 & 6 \\
\hline
 & 13 & 1 & 6 \\
 & & 11\frac{1}{2} & \\
\hline
13'\ 1\frac{1}{2}'' \times 11'' = & 12 & 0 & 5 \\
13'\ 1\frac{1}{2}'' \times \frac{1}{2}'' = & & 6 & 7 \\
\hline
 & 12 & 7 & 0
\end{array}$$

The result is 12 cubic feet, 7-12ths of a cubic foot; the 12th of a cubic foot must not be confounded with the cubic inch, as it really contains 144 cubic inches.

When the dimensions of an irregularly formed piece of work have to be taken with a view to bringing into "super." or "cube," it is usual to take the nearest average of the measurements, and enter them in the book as the actual dimensions, except in cases where the material has had to be cut away from the rectangular form, in which case its largest existing dimension must be taken as the true one. When great accuracy is required in taking the super. or cube of irregular shapes, the usual rules of practical geometry must be resorted to in order to obtain a true result. If circular work has to be measured,

the super. is found by multiplying the half-diameter by itself, and the result by $3\frac{1}{7}$; or in other words, multiply the square of the radius by 22, and divide by 7; this gives the super. of the whole circle; if it is only a half-circle, make 11 the multiplier instead of 22.

To find the "run" of circular work, multiply the diameter by 22, and divide by 7 for a whole circle; if for half a circle, let the multiplier be 11 instead of 22.

When a triangular piece of work has to be measured, take the length of one of the sides by half its perpendicular distance from the opposite vertex; these dimensions when multiplied together or "squared" will give the super. of the triangle. Other irregular figures can be measured in the same way by dividing them into triangles.

In most cases, however, where circular or irregularly shaped work has to be measured in buildings, it is necessary to take the full dimensions, as if it was rectangular, in order to allow for the labour expended in cutting away to fit the required contour.

In taking out quantities, or measuring work from a building, a "dimension book" is usually employed, either plain or ruled with vertical lines, the dimensions being entered on the left-hand column, and the description of work on the right hand, leaving the middle column for the "squaring" above described. For example, take a piece of flooring $14' 7'' \times 9' 2\frac{1}{2}''$. This is entered in the book thus:—

14 7 9 $2\frac{1}{2}$		$1\frac{1}{4}$ inch yellow deal floor.

A narrow column is always left on the left side of the dimensions in case the item has to be repeated, for if there happen to be three pieces of flooring of the same dimensions the measurer would then enter them in his book thus:—

3)	14 7 9 $2\frac{1}{2}$		$1\frac{1}{4}$ inch yellow deal floor.

And in squaring the dimensions he would multiply the "super." of $14' 7'' \times 9' 2\frac{1}{2}''$ by 3.

Suppose a number (say 9) of fir joists $11' 3'' \times 1' 2'' \times 11\frac{1}{2}''$ have to be measured, they will be entered thus:—

9)	11 3 1 2 $11\frac{1}{2}$		Fir joists.

When the measurements are all completed and entered in the dimension book, they will be "squared" in the manner above described, and the results entered in the middle column—thus:

3)	14 7 9 $2\frac{1}{2}$	402 11	$1\frac{1}{4}$ inch yellow deal floor.
9)	11 3 1 2 $11\frac{1}{2}$	113 3	Fir joists.

THE LATHE.—I.

By Henry Northcott.

INTRODUCTION — PRINCIPLE OF THE LATHE — SIMPLE ELEMENTARY FORMS OF LATHE.

"The invention of the lathe is very ancient; Diodorus Siculus says the first who used it was a grandson of Dædalus, named Talus. Pliny ascribes it to Theodore of Samos, and mentions one Thericles, who rendered himself very famous by his dexterity in managing the lathe. With this instrument the ancients turned all kinds of vases, many whereof they enriched with figures and ornaments in basso-relievo. Thus Virgil: 'Lenta quibus torno facili superaddita vitis.' The Greek and Latin authors make frequent mention of the lathe, and Cicero calls the workmen who used it *vascularii*. It was a proverb amongst the ancients to say a thing was formed in the lathe, to express its delicacy and justness."

The art of turning is one of the most ancient of the handicrafts, and it is as important as it is ancient. The paragraph I have quoted contains very nearly all the information we have upon the early rise of this art; and although its invention must certainly have marked an era in mechanical discovery, it must be allowed that we neither have any authentic knowledge of the date or manner of its invention, nor do we know to whom the world is indebted for it.

It is more than probable that the lathe was known, and the art of turning practised, long before either Pliny wrote or Thericles used the graver. Our indebtedness to the unknown inventor extends, however, very little further than the simple principle of producing an article of circular section through its rotation whilst being acted upon by simple cutting instruments applied to its periphery; and in the East, where in all probability the lathe had its origin and the art of turning was first practised, the lathe remains to this day unimproved and rude. With this, as with numerous other inventions, the land which gave it birth has been quite unable to bring it to maturity. A principle, simple and apparently trivial, but in reality possessing immense "potential" importance, has been neglected, applied to trifling and useless purposes, so that it remained a dwarf—curious and interesting, it is true, but without growth and without expansion. Eastern inventions are well typified by the grains of corn found in their mummies. How old they are we know not, but that they have laid dormant many thousands of years is quite certain. Discovered by an enterprising and searching European, and by him transferred to more congenial soil, they make manifest more vitality in a month than under previous conditions they would have shown in an eternity.

The simple principle, however, of the lathe is so apparent that it may have been, and very possibly was, discovered by more than one person, in more countries than one, and at more times than one. But this much is certain, that whenever the germ was discovered, it has remained until almost within the memory of the present generation as apparently unimportant as a grain of mummy-wheat. Now, however, we find it has become one of the most useful machines the mind has ever yet devised. In its original form it may be described as being an instrument for producing the circle, and turning as the art of producing and arranging these circles; whereas now the lathe is better described as a machine for producing anything. The art of turning appears to have been extensively and very successfully practised throughout the Continent of Europe during the sixteenth, seventeenth, and eighteenth centuries, although even then the lathes in use were extremely rude, but they embodied several ingenuities, and are very decided improvements upon the original form. Many writers of that period upon mechanical matters allude to the lathe and its productions; and in France especially the art was of sufficient importance to form the subject of some treatises on turning of great magnitude and completeness, and which even now may be read with interest and advantage. The two most important of these works on turning were, it cannot be doubted, Plumier's "Art de Tourner" in one large volume, and Bergeron's "Manuel de Tourner" in three volumes, both of which treatises contain a very complete exposition of the then state of the art.

In lathes of the simplest form the article to be turned is placed between two conical points, called centres, which, by forming two conical pits or indentations in the ends of the wood, serve to support it whilst it is being rotated and acted upon by the cutting-tools. This will be understood from Fig. 1, which shows a lathe of very primitive construction, and probably one of its earliest forms. It consists merely of two horizontal pieces of board fastened to and supported by two upright pieces, but arranged so as to leave a space between them. One of the uprights is continued above the horizontal bearers, and is furnished with a short rod of iron, the end of which is ground to a point. Another similar piece of iron is supported by a movable block of wood, called a puppet or poppet, and which is arranged to move up and down between and upon the horizontal bearers, so as to take in between its centre point and its fellow articles of any required length within the limits of the bearers. This puppet is fastened to the bearers by a wedge underneath. The rotation of the work is effected by means of an elastic piece of wood, furnished with a long string, so as to cause it to resemble an ordinary bow from which arrows are projected. The string is wound round the piece of wood two or three times, and is kept tolerably tight upon it through the

elasticity of the bow. On moving the bow backwards and forwards with a reciprocating motion, the string necessarily causes the wood to rotate, also in alternate directions. The tool is held in the right hand, and supported upon the tool-rest shown in front, and which also may be moved up and down upon the bearers, and fixed, when necessary, by means of a wedge underneath them. In the East, the workman sits whilst working, and steadies the tool by his big toe. The tool, of course, can only be applied to its cut whilst the work is rotating towards it, and is slightly withdrawn when it is running backwards.

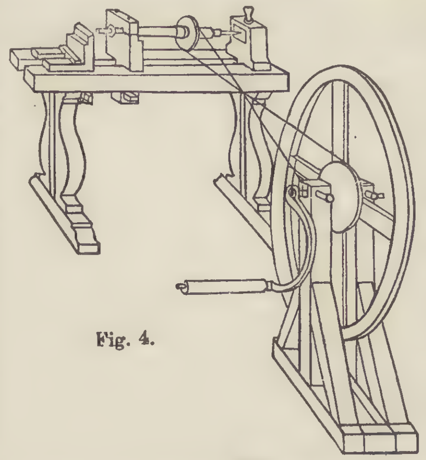


Fig. 4.

Clumsy as this apparatus is, rude as are the tools, and clumsy and rude as are the position and system of working, nevertheless, results have been produced that cannot be surpassed by the most delicate and complicated mechanism of modern times. The time and patience necessary for the production of good work by such means are, it is true, enormous, but that articles of surpassing beauty and delicacy have been produced is incontestable; and the simple principle of this lathe transplanted to more productive soil has been improved upon until we have the splendid and complete machines of Whitworth and Holtzapffel. One of the earliest modifications of this lathe was probably that shown in Fig. 2, in which, as will be seen, the bow is retained, but is placed overhead, and a string coming down from it passes around the work, and is attached to a treadle underneath. The work is rotated in the direction for cutting by depressing the treadle, which pulls down the cord, and thus draws round the wood around which the cord is wound; and when the pressure of the foot is removed, the elasticity of the bow pulls the cord and treadle upward, ready to be again depressed by the operator's foot. The table carrying the centre-point is raised upon legs. With this lathe the operator is enabled to stand to his work, and using his foot to give the article motion, he has both his hands to manipulate the tool.

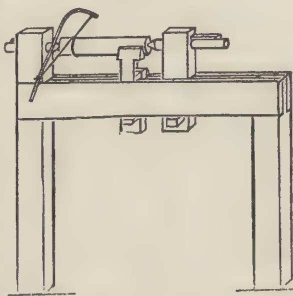


Fig. 1.

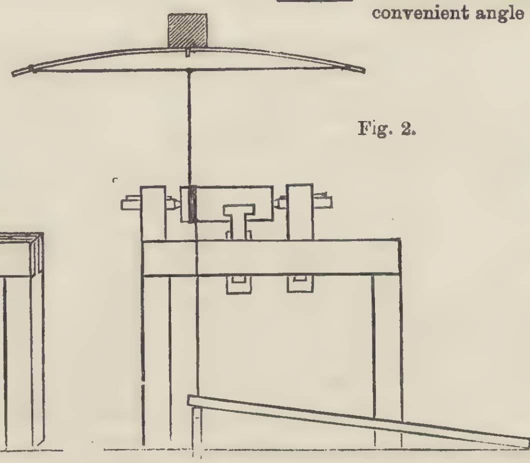


Fig. 2.

In both of these lathes the driving-cord is wound round the work itself, and this, of course, made it necessary that the rough piece of wood should be much longer than the finished length of the article to be cut from it. Another great drawback arises from the liability to break the piece of wood by the alternate upward and downward strains of the cord. Of course, as the treadle is depressed, there is a strong tendency to pull the wood also downwards out of the centres, or to break it into two, and there is a pull in the opposite direction as the cord is drawn up. When turning large pieces of wood these strains are not of much account, but when the work becomes small and slender, much care is required in treading to prevent an accident.

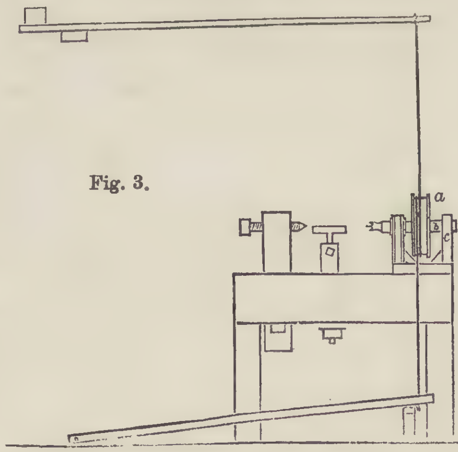


Fig. 3.

The inconvenience arising from these causes no doubt led to the application of a separate spindle to the poppet, as is shown in the lathe at Fig. 3. This lathe is substantially the same as the others, the motion being obtained by means of a treadle and cord, but the cord is pulled up by means of a long elastic lath, from which it is supposed the term "lathe" was derived, and the cord, instead of passing round the work itself, is wound round a wooden pulley, *a*, placed upon an axis, *b*, and rotates in two collars, *c*, or bearings, forming part of the poppet. The motion is thus given to the axis *b*, and to this axis the work must be attached in such a manner as to be rotated by it. The other centre is carried by the moving poppet as before; but in this figure the centre-point is shown as having a screwed thread, which allows of more convenient adjustment than the early plan of a plain cylinder held by a wedge. The tool-rest, also, is an improvement upon the former, it being formed with a socket and a tightening screw at the side, so that the support for the tool could be placed at the most convenient height and most convenient angle for presenting the tools used to the work. The general method of using this lathe was much the same as the others, the tool being only applied when the work was running round towards the workman, and slightly withdrawn during the backward stroke.

It should be noted that in using these lathes the proper arrangement of the string is such that the work is caused to rotate towards the workman, and consequently in the direction proper for being turned or cut, by the downward pull of the treadle; in other words, the work must be pulled round in this direction by the power of the workman's foot, and not by the elasticity of the lath or bow overhead. I have never seen one of these lathes at work, but am told that even in this country they are still not unfrequently used.

Rotation in alternate directions is, however, a very great inconvenience, and with any but hand tools would be fatal to the production of satisfactory work. The most obvious means of producing continuous rotation in the same direction is to have a separate driving-wheel, and employ an assistant to turn it round. A lathe so driven is shown in Fig. 4. It is scarcely necessary to explain that the large wheel of the drawing is turned by a boy, the lathe-spindle driven from the fly-wheel shaft by a cord or gut, and the work driven from the spindle in any convenient manner. The lathe as shown is designed more especially for the manufacture of short articles, such as can be attached firmly to the lathe-spindle without requiring the support of another centre-point. But, of course, the moving puppet can be used with a lathe of this sort if necessary.

TECHNICAL DRAWING.—XLVI.

DRAWING FOR MASONS.

FREE-HAND DRAWING FOR STONEMASONS.

It is now desirable to give the student some further practice in free-hand drawing, and for this purpose Fig. 425 is chosen.

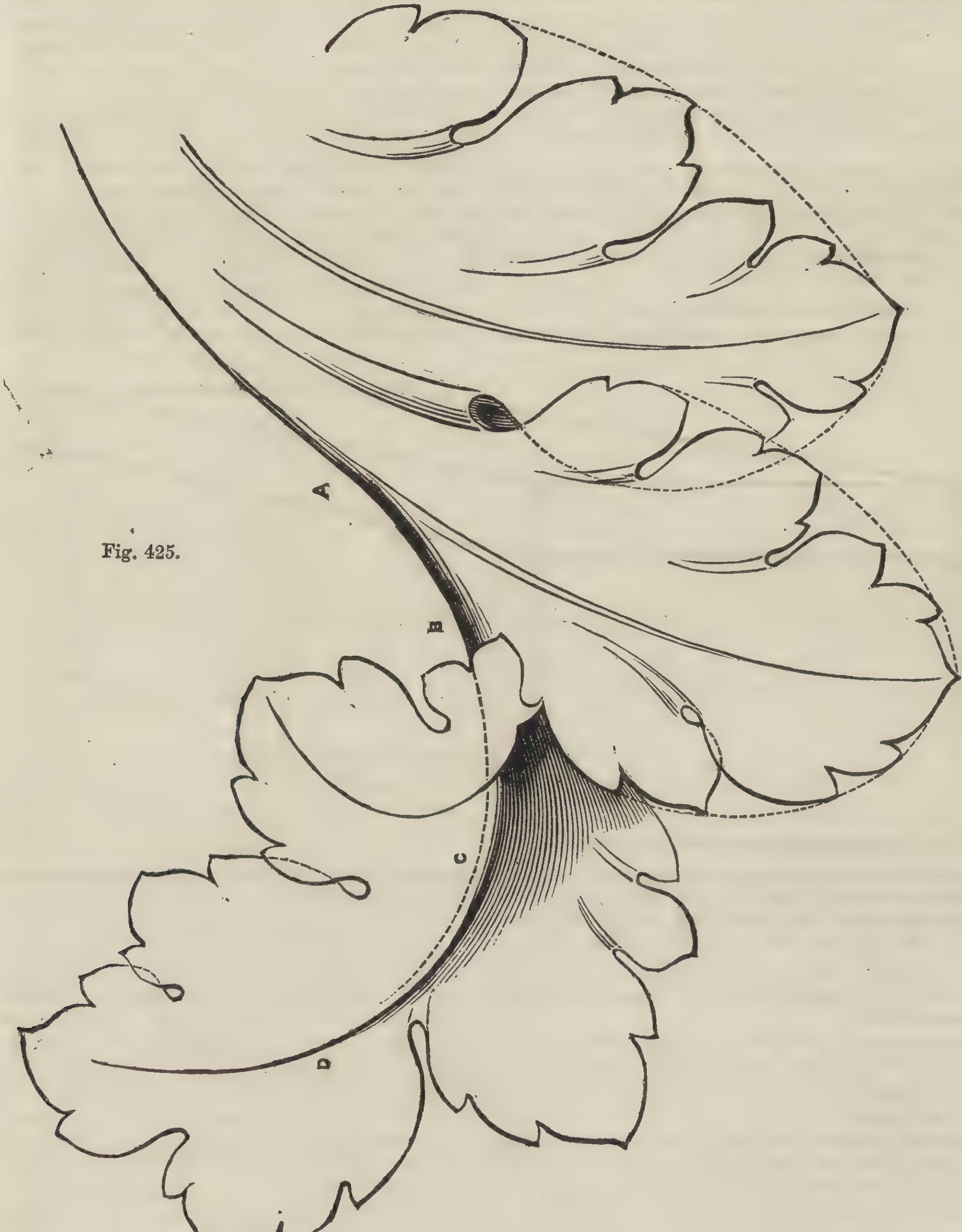


Fig. 425.

In drawing or carving, the student must bear in mind that all vegetable forms must be considered from two points of view—namely, the *actual* and the *conventional*, or (1) the manner in which the plant grows, and (2) the way in which it may be adapted to purposes of ornamentation; and it must be clear that the latter should be based upon the former, for however much the designer may arrange the forms, he cannot with propriety alter the mode of growth, place leaves on flower-stalks, or give parts to flowers which they do not possess.

There exists in all natural objects a law of symmetry which all who wish to rise above the rank of a mere labourer in art would do well to examine and to follow. On this point, Dr. Lindley says—"Symmetry may be defined to be the general correspondence of one half of a given object with the other half, in structure or other perceptible circumstances, or the general correspondence of one side of an object with the opposite side in structure or other perceptible circumstances.

"Take any leaf: if we separate it from end to end (along the mid-rib), the one half bears a most striking resemblance to the other; on the one side the veins run to the right, on the other to the left—perhaps those to the right are a little above those to the left; in that case the difference is maintained throughout. If there are four ribs on the one side, there are four on the other; and if you measure them off, provided the leaf has met

with no accident, the one vein is as nearly as possible of the same size as the other. If you place the edges against each other, their little indentations will almost fit. In all plants there is the same remarkable correspondence between the opposite sides or contiguous halves of the same leaf." The example here given is a portion of an acanthus leaf, in which this beautiful symmetry is well displayed.

In drawing this, the curve (A) forming the mid-rib should be drawn first. It will be seen that this is interrupted at B by the portion of the leaf which turns over and covers it. The line should, however, be carried on to C, as if the leaf were transparent, so as to form a guide for placing D, which is the inner edge of the mid-rib; and this, if continued, should fall within A B.

The separate parts of the leaf are to be drawn in masses, as shown by the dotted lines, the separate indentations being drawn when it has been ascertained that the general containing forms are correct.

In order to gain additional practice, the student should copy this example when it is turned in various positions.

DRAWING FROM SOLID OBJECTS.

Although the whole subject of object drawing is treated of in a separate course of lessons, the present study, which is one of exceeding simplicity, but at the same time one from which the student may obtain a large amount of instruction, is here given, since the principles shown therein will be found of immediate use to the mason. For this reason he is therefore urged not to copy the drawing only, but to place slabs and blocks of stones in similar positions, and sketch them from various points of view.

By this system he will learn the practical application of the lesson, and will be able to use the knowledge he acquires in his daily occupation. He must not, however, be content with this simple study, but should follow out the complete course laid down in "drawing from objects."

The subject of the lesson (Fig. 426) is a slab of stone resting horizontally on three others placed on their edges.

It must be here impressed on the student that it is important that he should acquire the habit of sketching all objects in the broadest manner; that he should, as it were, *not see* the details until he has drawn the object as a whole. He should, in the first place, think of it as merely the packing-case in which it might just be contained, or as if all the apertures or vacant spaces were filled up; for it must be clear to any thinking mind that all interior forms, and all detail, must be dependent on the general outline of the whole.

In commencing the subject of the present lesson, draw the rectangle A B D C, which represents the end of the whole block, and which, since it is supposed to stand parallel to the picture, will retain its original shape.

From A, B, C, D draw lines to the point of sight, which point, however, need not be shown in the drawing, in order that the object may be drawn as large as possible. The back line E F will terminate the horizontal slab, and a perpendicular line from F will complete the general outline of the block.

Having placed the drawing upright, so as to obtain a just view of it, and having made any corrections which may be deemed necessary, the student will now draw the line G H, and from H the line H I, which will give the thickness of the slab, bearing in mind that the line H I must, like B F, converge to the point of sight.

The widths of the edges of the three slabs on which the upper one rests are now to be drawn, observing, that although they are all three supposed to be of equal thickness, they must each of them be diminished as they recede. The slightest observation will be sufficient to show that all objects appear smaller and smaller as they become more distant from the observer, and this effect is visible, whatever may be the size of the object. The horizontal line at the bottom of each of the slabs will in the present study be partly hidden. This would, of course, depend on the width of the slabs and the position of the spectator.

The principles of shading objects are given in the course of lessons on object drawing above mentioned, and to these the student is referred for more detailed information.

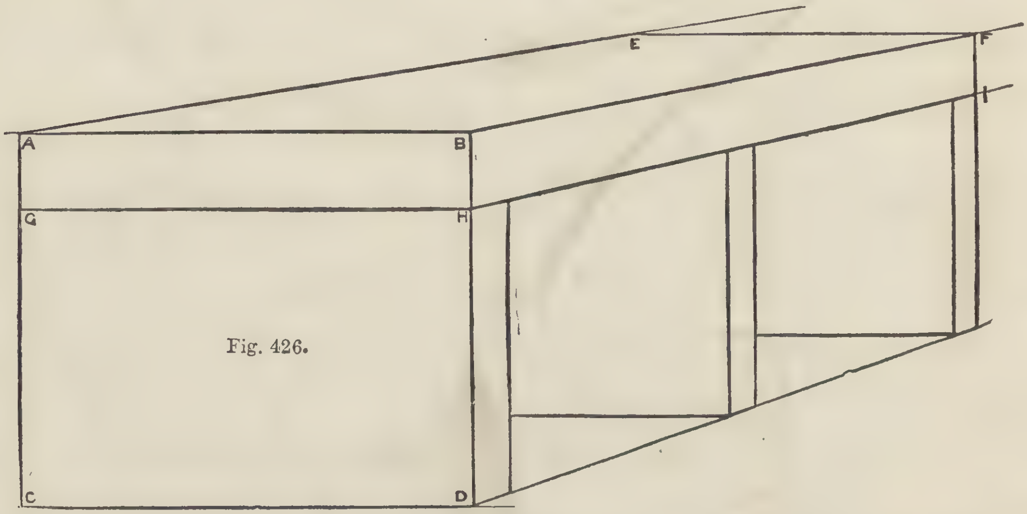


Fig. 426.

STAIRCASES.

It is deemed desirable to repeat in this place a portion of the lesson on stairs given under the head of "Building Construction," in order that the instruction may be carried further, and that it may be especially applied to masons' work. *Staircase* (stair, derived from the Saxon word *stæger*, to *climb* or *rise*) is a term applied to the whole assemblage of members, with the walls supporting the steps leading from one storey to another. The same staircase is often carried up throughout the whole height of the house, and may be said to consist of as many storeys as the building itself.

When the height of the storey is considerable, resting-places become necessary; these go by the names of "quarter-spaces" and "half spaces," according as the passenger has to pass a right angle, or two right angles; that is, as he has to describe a quadrant or a semicircle.

In very high storeys, that admit of a sufficient head-room, and where the space allowed for the staircase is confined, there may be two revolutions in the height of one storey, which will lessen the height of the steps; but in grand staircases only one revolution can be admitted, the length and breadth of the space on the plan being always proportioned to the height of the building.

The breadth of the steps of stairs in general use in common dwelling-houses is from 9 to 12 inches, or at about 10 inches as the medium.

In the best staircases of noblemen's houses or public edifices the breadth should never be less than 12 nor more than 18 inches.

Straight stairs are such as ascend in a straight line, and consist only of plane surfaces.

Winding stairs are those which turn around either a solid newel, or circular well-hole, the latter either enclosed in a complete cylindrical case, or semi-cylinder, at one end, adjoining to two parallel walls which terminate on an opposite wall.

In winding stairs, the steps are formed narrower next to the well-hole than at their other ends where they are built into the wall. These are termed *winders*.

Those steps which continue of the same breadth are termed *flyers*, in contradistinction to the *winders*.

GREAT MANUFACTURES OF LITTLE THINGS.—I.

STEEL PENS.

BY CHARLES HIBBS.

It is computed that there are 15,000,000 steel pens made in Birmingham every week. If the "grey goose quill" were still the universal instrument for recording the written thoughts of men, what a stupendous army of geese we should require to maintain, in order to furnish a like quantity! This consideration sets us speculating on what would have been the possible consequences if that nameless artisan of Sheffield, who, it is said, made the first steel pen, had not hit upon that ingenious and happy expedient. There is a story of an impecunious Irishman, who having been fortunate enough to find half-a-crown, immediately expended in comforts for Biddy and the "childher," was gleefully expatiating on his good luck, when he was cut short by his better half exclaiming, "Luck is it—ye omadhaun! Sorra' the luck that's in it—what should we ha' done widout it?" What should *we* have done without coal gas, and railways, and lucifer matches, and the penny post? Somehow, these discoveries have seemed to fit in so exactly with the successive stages of modern progress—the invention helping the advance, and the advance making the invention a necessity—that we are struck with the same sort of admiration as that which led the simple youth to wonder why great rivers always flowed past populous cities. We are now beginning to inquire beforehand (a thing we are not addicted to, in a general way) what we shall do when our coal supply is exhausted? Well: somebody will invent a new method of extracting heat from the substances around us, or perhaps find out how to re-capture the heat we have already set free, and which is still in hiding somewhere in our economy:—

"Kind Nature hath a thousand gifts in store
Unused, for man to chance on in his need;
And though to mortal ken she waxeth poor,
By reason of the treasure she hath freed,
The seeming waste doth but provide the seed
Which newly in her bosom multiplies:
Thus youth is bred of age, and nothing dies."

Birmingham consumes fifteen tons of steel per week in the manufacture of steel pens, probably a larger quantity than is used in that armoury of the world for the making of warlike weapons; so that, in this sense at least, "the pen is mightier than the sword." It would take a goose twelve months to grow a quill pen fit for use; even supposing the wing of the living bird to be plucked once a year, as was formerly the barbarous custom. It does not take Birmingham so long to produce its metallic substitute, as we shall see, if we follow it from its birth to its maturity.

It first appears in the form of sheet steel. The rolling of steel for pens is a work of great nicety, having to be performed with scrupulous regard to even thinness throughout; or otherwise no accuracy of tale in the subsequent stages would be possible. The pens, it will readily be apprehended, are not counted into grosses, but weighed; and one gross should weigh exactly the same as another gross of the same pattern. When cutting up the sheet into strips, therefore, the workman carefully gauges every part of the steel, and rejects all that is unequal in the slightest degree. The first business is to shred it into long strips or ribbons, of a breadth sufficient to allow of two pens being cut out of it end to end, the points slightly overlapping each other. These strips are given out to the cutters; and here begins the first of the many processes for which the nimble and delicate fingers of woman are found of inestimable service. The number of girls and women employed in the steel-pen trade, in proportion to the men, is about twenty to three. The employment is light and cleanly, and as suitable for women as any mechanical art can be said to be. The cutter-out sits before a small press, in which is fixed a die, having a hole cut through it the exact shape of the pen. A punch fitting this hole to the utmost hair-breadth nicety, rises and falls with the motion of the press-handle, and being sufficiently depressed, enters the orifice with a sucking motion, suggestive of its beautiful fit. The girl places the end of the ribbon on to the die, from the back of the press, with her left hand, while with the right she gives a little jerk to the handle; the punch descends, bites through the metal, and the pen blank, cut out very cleanly and neatly, falls through. Such is the process of cutting out a single pen; but during the time it has taken the reader to peruse this description, the girl would have cut out the whole length of ribbon into a beautiful diaper pattern, each perforation representing a pen, and the spaces between each of the most mathematical regularity.

These blanks are then taken to the piercing-room, where the little ornamental holes about the nib are cut out with precisely similar tools. In a well-regulated factory, each operation is performed in a room isolated from all the rest, large, lofty, and well lighted, and presided over by an overseer, who is commonly the skilled workman who makes and sets the tools. This process is not quite so quickly performed as the last, the blanks having to be placed one by one on the die with the fingers, but still it is very rapid. Small projections of steel, called guides, are fixed upon the bed, by which the girl is enabled to place the pen on its precisely proper spot in an instant.

So far the steel, moderately hard from the rolling, will bear being cut and pierced without fracture, but would not endure that much greater liberties should be taken with it. The pens have therefore to be annealed, to make them of a more yielding disposition. This is done by placing them in shallow iron pans in a "muffle," or reverberatory furnace, by which they are heated regularly throughout to a dull red, and, being suffered to cool, become so soft, that they may be bent in any direction without breaking. They are then taken back to the marking-room.

Some pens are marked with incised letters or devices, indicating the name of the maker, or the distinctive appellation of some particular pattern. Others have an ornament embossed upon them in considerable relief, such as the Queen's head, for example. In either case, these markings are impressed by a stamp. Perhaps the most wonderful of all the operations, for quickness of eye and hand, is the marking. The marker sits down to her work, as do all the female workers at the other branches. She has one foot in the loop of the rope, the bed of the stamp being before her on the bench. She takes a handful of pens, all lying confusedly, from a heap with the left hand, and by a dexterous palming motion, marshals a little procession of them between the thumb and forefinger in parallel order, presenting the foremost in a convenient position to be seized. The right hand travels backward and forward to the stamp about twice in a second, each time taking a pen, turning it over point foremost and right side up, and placing it exactly under the descending punch, which she causes, by the motion of her foot, to give a constant succession of blows in regular beat, almost as quick as they could be counted. The nimble fingers play in and out under the heavy stamp hammer with an airy indifference to danger which quite reassures the spectator, though it is evident that the slightest miscalculation of time or distance would make a case for the nearest hospital.

It has been mentioned that the marker has to place the pen right side up. This requires explanation, since it might be supposed that so long as the pen was in flat, which it is up to the marking stage, it would have both sides alike, and that it would be a matter of indifference on which the mark was impressed. This, however, is not so, and for the following reason. When the pen is pierced, the cutting tools leave a slight—very slight—burr, or roughness on the edge of the cut, on the under side. At an after stage, this rough edge, which can scarcely be perceived, but may just be felt with the finger, is polished off smooth and level, so that it is important it should

be kept on the outer side of the pen. The marking, if it consists of incised lettering, must be impressed on the outer side also, or otherwise it will read backwards, while, if it is an embossed or *repoussé* pattern, it must be raised from the under side. The workwoman, therefore, wants some mark or indication, to inform her on which side she is operating, just as the compositor who set up this article required a mark on his types to prevent him from putting his letters upside down. Now, if the reader will take up any steel pen that happens to lie within reach of his hand, he will perceive a microscopic indentation, which looks like a slight accidental defect, on one edge, towards the butt of the pen, where it would be hidden by the holder. This is the mark referred to, and it is obtained by purposely damaging the cutting punch in that particular spot. In marking or embossing, the operator has, of course, to keep this mark to the right or left, as the case may be.

The next stage is the "raising," or bending the pen into the shape required. Some are bent round simply into a curvilinear form; others have a ridge, like a backbone, running down the centre; others, again, have shoulders raised, or are bulged out in odd places into a conformation of the Quasimodo order. The press is the instrument with which all these transformations are effected, and the thin ductile metal readily takes and retains any impress that may be given to it.

The pens are now beginning to assume the appearance of maturity, though they are far from having really reached it. Their constitution is still limp and enfeebled from the softening, and they have no more elasticity than so many pieces of pewter. They have now to be braced anew in the hardening tub, and afterwards scoured to make them more presentable. The first-named process consists in again heating them to a dull red in the muffle, in shallow pans as before, and then overturning them into a bath of oil. A cullender of iron, suspended in the oil tub, brings up the pens and drains them, they having now a greasy, black, disreputable appearance, and a temper as brittle as glass. A good boiling in strong soda and water removes all impurities, and gives them a complexion sufficiently white and clear for the purposes of the next process, tempering, which requires some delicacy.

Perhaps all the readers of this serial may not be aware of that peculiar trait in the character of steel which enables an adept to render it, at his will, as pliant or as obdurate as he pleases. When heated to a sufficient degree of redness (not one scintilla more, or it will be burnt), and then cooled as suddenly as possible, it will have attained its maximum degree of hardness. Othello's exclamation, "I have a sword of Spain, the ice brook's temper," bore reference to a celebrated method of hardening blades in Toledo, by plunging them while red hot into a stream of icy cold water. If, on the contrary, the heated steel be forced, by artificial means, to cool very gradually, it becomes as soft as it can be made to be. Between these two extremes any degree of hardness or softness can be obtained by *tempering*. Suppose a piece of steel to have been thoroughly hardened, afterwards re-heated to a certain degree, and suffered to cool gradually, it will have been softened precisely to the degree to which it has been re-heated. The adept knows exactly the degree of softness it has acquired by watching the changing colour of the metal under heat. First, it will become of a pale yellow or straw colour; this will deepen gradually into orange; then, by a beautiful gradation of tint, into a rich purple; thence into a deep blue; from that again into a pale blue; after which the colour will fade away entirely, and the metal become white again; the next stage being red heat. Any reader can test this for himself by laying a needle upon a hot poker. If the heating be arrested at any one of these stages, the steel will be of a temper corresponding to that stage. No subsequent re-heating will alter this temper, though repeated again and again, provided it stops short of the point to which it has proceeded before: thus, a piece of steel which has been tempered to a purple, may be afterwards brightened and brought to a purple again without injury; but if it be heated till it becomes blue, its temper will have been reduced to that extent. This last explanation must be borne in mind, when we come to speak of a later process in the production of our pen.

The dark blue stage is the one which gives that degree of elasticity to the steel pen which makes it an efficient substitute for the quill. Now, if the reader will kindly repeat that little experiment with the needle and the poker, he will appreciate the difficulty of heating so small an article equally throughout, so as to ensure its temper being even. He will find that the point will begin to turn colour soonest, and will be hopelessly softened before the thicker parts are tinged. The same thing would happen to a steel pen, if it were laid upon a surface ever so regularly heated, and would of course be fatal to the tapering nib, the temper of which would vary from heel to point. The difficulty is overcome by the following means:—Some hundred grosses, or so, of pens are placed together in an iron cylinder, which is made to revolve slowly over a number of gas jets; thus, turning constantly over and over each other, the pens turn colour in company with the utmost regularity, the operator who is watching the process taking out a little shovelfull now and then to see how they are getting on.

The next process is to scour and polish them. A quantity of pens, mixed up with something that looks like fine cinders, but which is in reality old casting pots pounded up, are put into a barrel after being well wetted. The barrel, which is of iron, is fixed upon the revolving shaft of the machinery, and churns the internal mass until every pen is scrubbed white. Another useful object is effected in the process, viz., the rounding off, by abrasion, of the raw outside edge of the pen, especially that of the point, which otherwise would be sure to scratch. A similar treatment with dry material, of a finer kind, puts a smooth surface on the pens, and makes them shine like silver.

They are then taken back to the work-rooms, and glazed. This means polishing a little off the back of the nibs, to give them elasticity, answering to the scraping of the old quill pen with a pen-knife. After this comes the important operation of slitting.

In the early days of pen-making, the method of doing this was the very deadest of dead secrets. It was performed with the utmost mystery in a locked and darkened room, the sacred floor of which no visitor, however distinguished, was ever allowed to tread. The work-people were picked and bound to secrecy. There was a tradition even that they were required to "kiss the book" before initiation. The slitting is shown as freely now as any other branch of the manufacture, and, like many another mystery, does not appear to have much in it when it is disclosed; in fact, it seems as simple and obvious as did the process by which Columbus made his egg stand on end. It is simply a cut made by a pair of scissors. True, the scissors do not resemble in the least that useful household instrument which bears the name, the two blades being square slabs of steel, with sharp corners rather than edges, fixed firmly in a press, the one made to slide nicely past the other. If there is any mystery at all in the matter, it is in the extreme nicety with which these tools must be fixed, to ensure the slit being clean, and exactly in the middle of the point. As proof of what may be done by skilful hands in this way, there were a number of pens shown by a Birmingham firm in the Paris Exhibition, which had six distinct slits within the width of an ordinary point, each being perfectly clean and sound, and, as shown under a microscope, at uniform distances from each other.

This process properly completes the series, but most pens are subjected to further treatment, in order to improve their appearance. Some are browned; which is done by heating them again in the cylinder, to the dark yellow point (this making no alteration in their temper, as before explained), and afterwards coating them with varnish. Some are blued over again, and sold in that state. Some are plated with copper, or gilt. Many, after being coloured, are again glazed crosswise, putting a bright belt upon them which looks lively, and perhaps adds a little to their elasticity.

Some idea of the extreme quickness with which these manipulations are performed may be derived from the fact, that steel pens have been made and sold in Birmingham for the incredible price of 1½d. a gross! A man need not be of more than middle age to remember the black barrel pens, the first steel pens of commerce, that were sold for a shilling apiece, more as curiosities than anything else, for they were no match for the easy-going quill. After all, a good quill pen was pleasant to write with, and so was travelling by road pleasanter than travelling by rail. But quills, like coaches, took up too much time. Who that remembers the misery of trying to write with a dilapidated quill that sputtered all over the paper at the first stroke, and after necessitating a search for something that might serve as a

pen-wiper, obstinately refused to be slit in a straight direction either by the incision of the pen-knife, or by the flick of the thumb-nail; at last suffering itself to be cut away right to the stump before it could be coaxed into writing as legibly as an ordinary skewer—who, that remembers this, but will prefer the neat and elegant little steel nib, which can be changed and fixed in a moment? There are some whose faith is yet built upon the quill, but they are of the same order as those who believe in wooden walls, muzzle-loading guns, and tinder-boxes.

FARMING AND FARMING ECONOMY.—VI.

By Professor Wrightson, Royal Agricultural College, Cirencester.

MANAGEMENT OF ROOT-CROPS.

Root-crop sowing commences with mangel-wurzel the last week in April, and is continued up to the middle of August. Swedes are sown in the north of England from the 10th to the last day of May, and in the south from the 1st of June to the end of the month. In the north, white turnips are best sown from June 10th to 20th, and in the south they are planted all through July and into August. Early sowing cannot be practised in the south on account of mildew, which is exceedingly liable to attack early-sown turnips.

In the following remarks it will be impossible to go into details with reference to all the root-crops usually grown. We must, therefore, content ourselves with an account of swede and turnip culture; and since the preparation of the land and the after cultivation is similar in the case of all our root-crops, these must be looked upon as fairly representative.

Methods of sowing.—Roots are sown on "the flat" and on "raised ridges." In the first method the land is brought into a clean, fine condition, and after harrowing, the seed is sown with a "drill" in rows from sixteen to twenty inches apart. In the ordinary forms of the implement, superphosphate or some other portable manure, mixed with ashes, is drilled with the seed at the rate of 3 to 4 cwt. per acre. Of late years a drill has been much used in the southern counties in which 300 gallons, more or less, of water are used per acre, in the place of ashes. The portable manure is added to and mixed with the water, and the whole is distributed from a tank by revolving buckets, conducting-tubes, and coulters, which carry the liquid to the ground, where it comes in immediate contact with the seed. A better distribution of the superphosphate, a quicker germination of the seed, with a more certain and regular crop, even in the most droughty seasons, are among the principal advantages of the water-drill.

Drilling on the flat is adapted for dry and rather light soils, where raising the land into ridges would be attended with loss of moisture from increased evaporation. This method prevails in the south, while raised ridges are most frequently used in the north.

The Northumberland system of raised ridges originated in Norfolk, from whence it was introduced into Roxburghshire by Mr. Dawson of Frogden, in 1764, and subsequently it spread into the fine turnip-growing district of North Northumberland, and finally over the whole country. It is difficult to convey an accurate idea of this method of "making turnips," as it is termed. The land being in proper tilth, an ordinary plough, or better still, a double mould-board plough, is used to raise up the finely worked soil into ridgelets of from 27 to 30 inches wide. The land will then present the appearance indicated by the continuous lines of the accompanying figure. Dung is carted

and spread carefully in the opened trenches, after which the ridges are split over the manure, as shown by the dotted lines. The result is a fine seed-bed, underlaid by moist farm-yard manure, and down the centre of every ridge the seed is sown by means of a two-rowed turnip drill, furnished with concave iron rollers which run upon, and level, the tops of the ridges. The arrangement of work-people and horses, and the expense per acre, will be readily seen in the accompanying statement:—

	£	s.	d.
2 teams rising and splitting drills at 8s. per day each	0	16	0
Say, 4 horses carting dung at 3s. each	0	12	0
2 men and 1 boy filling manure at heap at 2s. 6d. per man, 1s. 6d. the boy	0	6	6
1 man drawing out manure into small heaps in every third ridge	0	2	6
6 women spreading manure at 10d. per day	0	5	0
2 women sowing artificial manure at 10d. per day	0	1	8
½ time of 1 man and 1 horse sowing turnips on ridges	0	3	0
	£2	6	8

Or as 4 acres would be completed in one day, 11s. 8d. per acre.

The advantages of this system are, that the dung is placed immediately beneath the seed, that the horse-hoe can be used as soon as the plant is visible along the rows, and that the finely tilled soil is gathered up conveniently for the young plants.

The manuring of the root-crop is in itself an important question upon which much might be written. Farm-yard manure, superphosphates, and guanos are the principal materials used for the purpose, and the quantities employed per acre vary widely in different localities. We should recommend the farm-yard dung to be applied to the land nearest the buildings, and the roots thus grown to be carted off for consumption by cattle at the homestead. Turnips at a distance may be grown with the help of "artificial" manures, and fed upon the land with sheep. In this way cartage will be saved, and the land will be kept in good condition. With regard to the quantity of manures used, and the proportions in which they are mixed, we have collected the following information. Mr. Thomson, of Mongoswalls, Berwickshire, manures as follows:—For swedes, 20 single horse-loads of manure, 2 cwt. of Peruvian guano, and 3 to 4 cwt. of bone-superphosphate. When the crop is intended to be eaten off with sheep, one-third less is used. For turnips, 12 to 15 single horse-loads of farm-yard manure, and 3 cwt. of bone-superphosphate; or 5 or 6 cwt. of bone-superphosphate alone, when folded off with sheep. Mr. Lee of Dilston, for many years secretary to the Hexham Farmers' Club, tried several experiments between Peruvian guano and other manures at equal prices per acre, and three years out of four guano produced the heaviest crops. Mr. Wood, of Thornbrough, a successful Northumberland farmer, and a man of experience, writes as follows: "We generally give our swede turnips 15 to 20 cart-loads of farm-yard manure, and 3 cwt. of guano. Eight bushels of bones (dissolved at home with vitriol and mixed with sawdust and ashes) and 4 cwt. of guano produced the best crop of turnips that we ever had." Mr. Lee of Dilston informs us by letter that he has used for swedes 17 cart-loads of farm-yard manure, 1¾ cwt. of Peruvian guano, and 4 cwt. of dissolved bones. Again, for Palmer's yellow turnip on light land, 8 bushels of half-inch bones, 1 cwt. of Peruvian guano, 2 cwt. of Bolivian guano, and 3 cwt. of dissolved bones. Again, 8 bushels of half-inch bones, 1¼ cwt. of Peruvian guano, and 5 cwt. of dissolved bones. The writer has seen crops of mangel in Lincolnshire manured with as much as 17 cwt. of guano per acre. Such extraordinary dressings are, however, seldom met with, and the case last mentioned is probably unique. On the Cotswold hills the practice is to raise turnips and swedes with 3 cwt. per acre of "superphosphate," and probably from 3 to 4 cwt. of "superphosphate" is the most ordinary amount of manure used for this crop.

The land being ready, and the manure mixed, nothing remains but to sow the seed at the rate of 3 pounds per imperial acre, either on the flat or upon the ridge. If the weather is favourable the young plants will show themselves in less than a week, and immediately on their appearance they are subject to the attacks of the turnip-fly, or, as it should be more properly called, turnip-beetle. This small beetle appears with the turnips, and has been apparently waiting for them, feeding the while upon charlock, Jack-by-the-hedge, and other cruciferous plants. The turnip appears above ground with two cotyledon leaves, which are soon replaced by the ordinary lyrate leaf of the tribe, with its characteristic roughness or smoothness according to species. It is only while in the early phyton state that the turnip is subject to the attacks of the "fly," and as soon as it is fairly into the rough leaf the

beetle is powerless. This pest will, in droughty weather, frequently clear off a whole field, leaving nothing but the tender young foot-stalk entirely denuded of leaves. In such cases the only course open to the farmer is to sow again, and in some cases he may have to sow a third time before he succeeds in obtaining a plant. Many plans have been proposed in order to destroy or evade this enemy of turnip culture. Without further comment we give a few of the best known recipes, founded upon the principles of destruction, for rendering the insect's food unpalatable, and of diverting his attention by feeding him on something which he will prefer to the crop. Among the first methods, it has been proposed to sow a small batch of turnips in a field corner; the result being that this piece becomes speedily infested, and successive hordes of beetles may be in turn destroyed. The means proposed for this end are as follow:—

Take a board and support it on wheels; tar it on the under side, and then draw it over the young turnips. The instant the shadow of the board passes over the unsuspecting turnip flea, he leaps up, and adheres to the tarred surface. A tarred rope dragged over the land has been used with similar intent. Fine dust has been sprinkled over the young leaves before the dew has evaporated, in order to render their home uncomfortable. The late Mr. Fisher Hobbs' mixture for this purpose consisted of 1 bushel of white gas ashes fresh from the gas-house, 1 bushel of fresh lime from the kiln, 6 lbs. of sulphur, and 10 lbs. of soot, all well mixed together, and reduced to as fine a powder as possible; this will be sufficient for 2 acres of land. Another mixture recommended by Mr. Hobbs was 14 lbs. of sulphur, 1 bushel of fresh lime, and 2 bushels of road scrapings per acre; mixed for a few days previous to application. Road scrapings alone have also been used with good effect. A third method consists in sowing plenty of seed, and as the insect is partial to white turnips, it is well to sow some of this seed with the swedes, and to hoe out the white turnips at the time of singling. Ingenious as some of these methods are, most farmers risk the chances against the fly, and take no precautions to prevent its ravages. The turnip is subject to many other insect attacks, such as the wire-worm (*Elater obscurus*), the black-jack (*Athalia spinarum*), and the surface grub, which name appears to be applicable to the larvæ of several moths. Aphides and mildew are also frequently trying to the crop, and render it uncertain.

The after cultivation of turnips and swedes consists first in horse-hoeing between the rows; then in singling or thinning; thirdly, in horse-hoeing and hand-hoeing combined; and lastly, in a third horse and hand hoeing. Hoeing is important both as a means of stimulating the growth of the crop, and keeping the land clean. In singling, the plants must be set at a proper distance apart: from 9 to 12 inches for white turnips, and from 14 to 18 inches for swedes, are good intervals. The best plants must be left, all weeds must be cut, and all the soil should be stirred with the hoe. The gate is now closed, and the young plants are left to the influence of a genial moist autumn, which will probably give us from 15 to 20 tons per acre of valuable winter food, and in the case of mangel-wurtzel we may look for from 20 to 25 tons. We shall next have to consider the best means of storing and consuming our root-crop, and lastly calculate the cost of producing it. When swedes or turnips are fed upon the land, they are either eaten *in situ* by sheep, or are placed in heaps convenient for the turnip-cutter. In the first case, no labour is necessary except the shifting of the sheep hurdles. In the second case, the turnips are pulled, thrown together into heaps, and covered with a protecting layer of straw and earth. When required for cattle they are carted off the land, stored conveniently for the buildings, and covered up from the frost with straw, and sometimes earth in addition. In all these cases it is well only to cut the tops off, and to leave the roots untouched. White turnips are seldom stored for any length of time, but swedes will keep till May.

We have been compelled to treat this subject with unbecoming brevity. Every one conversant with farming matters knows that each point touched upon in the above outline of turnip cultivation is worthy of thorough discussion; but such, we apprehend, is scarcely the object of the present series. In concluding this part of the subject, we append a detailed estimate of the cost of the various operations described.

COST OF GROWING A CROP OF SWEDES.

	£.	s.	d.	£	s.	d.
Paring stubble				0	3	0
Rolling and harrowing				0	2	0
Gathering weeds				0	2	0
Burning				0	3	0
Carting manure				0	5	6
Spreading do.				0	1	6
Deep ploughing				0	9	0
Spring cultivation: say 1 ploughing 8s., 2 cultivators at 3s., harrowing 1s. 6d., rolling 9d.				0	16	3
Sowing on the flat				0	2	0
Expenses on mixing ashes and superphosphate				0	2	4
Singling				0	4	6
Second and third hoeing by hand				0	5	6
3 horse hoeings at 1s.				0	3	0
Heaping				0	7	0
Total horse and manual labour				£3	6	7
Seed 3 lbs. at 1s.				0	3	0
				£3	9	7
Manure: $1\frac{1}{2}$ cwt. of guano at 14s.	1	1	0			
3 cwt. of superphosphate at 6s.	0	18	0			
				1	19	0
				£5	8	7

To this may be added rent and taxes, say £2, if we view rent as an expense. It is, however, more correct not to do so, as rent is really a share of the profit, due to the landlord. Again, we have not charged for farm-yard manure, as this and future calculations will be simplified by allowing the farm-yard dung and the straw, neither of which are in ordinary cases saleable commodities, to cancel each other.

BUILDERS' QUANTITIES AND MEASUREMENTS.—II.

BY E. WYNDHAM TARN, M.A.

Having "squared" all the "dimensions," as shown in our first paper, the next operation which the measurer has to perform is that called

ABSTRACTING.

This process consists in taking a sheet of paper ruled into vertical columns about one inch wide, and having the titles of the several artificers written at the top; one, two, or more columns being devoted to each trade, as the circumstances and number of different items may require. We shall give a specimen of an abstract sheet under each trade as we proceed, so as to show how the several items are arranged therein.

Having prepared the abstract sheet, we next proceed to abstract all the measurements from the dimension book, and enter them in the several ruled columns in regular order, dimensions of the same kind of material or workmanship being entered immediately under each other, so that they can be added together when all is completed. It is very essential in abstracting to carefully classify the different materials, having separate columns for "numbers," "runs," "super." and "cube," as well as for articles of different quality or thickness.

When all the measurements have been abstracted from the dimension book, each item being struck out as it is abstracted, and all those of the same sort are added together, the measurer next proceeds to reduce the quantities to their various standards of measurement, whether feet, yards, rods, squares, or otherwise, which will be explained under the headings of the several trades as we proceed. The next and last operation of the measurer is called

BRINGING INTO BILL.

In this process the whole of the items are taken out from the abstract and placed in order on ruled bill paper, commencing in each trade with cubed work, which is followed by super. work, then the runs, and lastly the numbers or articles which are taken at so much apiece. The quantity of each kind of work is placed in the left-hand column, and on the right hand is a column for the prices to be affixed to each item, and three columns for the £ *s. d.* to which each amounts when priced out. We shall hereafter give a specimen of a detailed bill of quan-

tities, which will explain for itself the system adopted by surveyors and measurers in the final process of their work.

We shall now proceed to explain the modes in which the foregoing rules are applied in the various trades which are employed in building operations, as each has its own peculiarities, there being also variations in the same trade in different parts of the kingdom. As, however, the system adopted by London surveyors is generally recognised in all large towns, we shall confine our attention chiefly thereto.

EXCAVATING.

The work of the excavator is *digging* out the ground to form the basement storey, the trenches for foundations, and for laying the drains. Where there is a basement storey and vaults, measure them first, taking the length, breadth, and average depth; the length and breadth should be taken about six inches outside the greatest projection of the footings of the outside walls, unless there is an area round the building, in which case the dimensions must include the width of the area. Next measure the length of the footings, or foundation of the walls, by the width, adding at least twelve inches thereto to allow for laying the bricks, in case there is no concrete below the footings; but if there is a concrete bottom measure the nett or exact width of the concrete for the digging; the "super." thus obtained must be multiplied by the depth of the bottom of the foundation below the floor of the basement story, as previously measured. The trenches for the drains must be taken at least eighteen inches to two feet in width, and in all cases six inches must be allowed on each side of the drain to give room for laying. It is necessary to keep all these items separate in the dimension book, as the earth excavated from the footings and drains will be partly filled in and rammed, which must be described against the items in the book. The depth to which the earth has to be excavated, and the nature of the soil must also be stated; if the depth is under six feet, it is called one *throw*; but if more than that, it is charged extra as two throws, down to twelve feet; beyond that as three throws, to eighteen feet, and so on. When the earth has to be removed from the premises, state how far, and whether in barrows or baskets, at so many *runs* of twenty yards each, or in carts at per mile. If the earth to be excavated from trenches is of a loose nature, it may be necessary to provide planking and strutting to keep it from falling in while the wall is being built or the drains laid: this is generally taken separately, at per yard run, describing the depth and width of the trench.

All excavated earth is estimated by the cubic yard, so that the number of cubic feet brought into the abstract must be divided by 27. Cellars or vaults built underground, and covered by earth, have to be first covered with a layer of "clay puddling," six inches thick, to keep out the wet; this is measured by the "super.," and in the abstract the number of feet is divided by 9 to bring it into yards. Also, where earth has to be spread over a surface at a depth of not more than twelve inches, it is taken in the same way, and brought into super. yards.

The following example will best explain the mode of entering the dimensions of the excavator's work:—

21 6 17 9 5 3	2003 9	Digging in clay soil for basement storey and cellars, 1 throw, and carting 1 mile.
97 9 3 6 2 3	769 11	Ditto, ditto, to foundations, 2 throws, partly filled in and rammed, and partly wheeled two runs.
123 8 2 3 7 6	2086 11	Ditto in gravelly soil, trenches for drains, 2 throws, filling in and ramming.
12 6 9 3	115 8	Clay puddling over vaults.
50 0 32 6	1625 0	Spreading earth and levelling ground.
123 8	123 8	Planking and strutting to trenches 7′ 6″ deep, 2′ 3″ wide.

ABSTRACT.

C. Digging in clay and carting. 27)2003 9(74 c. yds. 5 ft. 189 113 108 5	C. Digging in clay, 2 throws, part filled and rammed, part wheeled 2 runs. 27)769 11(28½ c. yds. 54 229 216 13	C. Digging in gravel, 2 throws, filling in and ramming. 27)2086 11(77¼ c. yds. 189 196 189 7
Sup. clay puddling. 9)115 8 12 yds. 8 ft.	Sup. levelling earth. 9)1625 180½ yds.	Run planking & strutting to trenches, 7′ 6″ deep, 2′ 3″ wide. 3)123 8 41¼ yds.

WELL-SINKING.

The digging and sinking of wells and cesspools are measured together, including steening, or laying brickwork without mortar round the well. They are taken at so much per foot of depth, describing the diameter of the well in the clear. If the brickwork is laid in mortar or cement it must be described as such. The character of the soil through which the well passes must also be mentioned. If water has to be pumped out of the well while the work is in progress, the cost is charged separately at per gallon.

Boring is taken by the foot depth, but increases in cost per foot as the depth increases; the nature of the rock must be stated, and also the diameter of the bore required.

PRINCIPLES OF DESIGN.—XXIII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

POTTERY AND EARTHEN VESSELS (*continued*).

In this chapter I purpose devoting special consideration to the shapes of earthen vessels, and then noticing the manner in which ornament should be applied to them.

In his primitive condition man appears to have used the shells of certain fruits as drinking vessels and bottles; and to this day we find many tribes of uncivilised or half-civilised men using the same class of vessels. "Monkey pots" (the hard shells of the *Lecythis allaria*), the coverings of the Brazil nut, (*Bertholetia excelsa*) and especially the rinds of the calabash and many species of gourd (Figs. 81, 82), have been used in this way.* The first efforts made at the production of earthen vessels were mere attempts at copying in clay the forms of the fruit-shells which they used. After a power of forming earthen vessels, having a certain amount of perfection of manufacture, was gained, we still find the origin of the art manifested by certain works. Thus in China, where the potter's art has so long been understood, we still find vessels made in the form of the bottle-gourd, just as was their custom in the days of their first manufacturing efforts (Fig. 83). Before considering the shapes of vessels from a utilitarian point of view, I should tell the student that certain shapes are characteristic of different nations and of different periods of time.

The Greek shapes, as we may call them—that is, the forms of those vessels which the Greeks produced—are of a particular class, and the vessels produced by the Egyptians are of a different type; while those of the Chinese, Indians, Japanese, and Mexicans again differ from each other, and from those of both the Greeks and the Egyptians. For grace of form the vessels of the old Greeks stand pre-eminent; for simple dignified severity, those of the Egyptians; for quaintness, those of the Mexicans; for a combination of grace with dignity, those of the Chinese; and for a combination of beauty with quaintness, those of the Japanese; while in many respects the Indian shapes resemble those of the Japanese.

I cannot enter into any details respecting the characteristic forms of vessels produced by these various nations, but must content myself by giving a few illustrations of the various shapes, and leaving the matter with the learner for study. The

* All who are interested in this subject are referred to a paper published in the "Transactions of the Edinburgh Botanical Society," for 1859, by Professor George Wilson, on the "Fruits of the Cucurbitaceæ."

British Museum, the South Kensington Museum, and the Indian Museum will aid him in his researches.

It has been said that the character of a people can be told by their water-vessels. As the consideration of this statement will lead us to see how perfectly a domestic utensil may answer the end which it should serve, I will extract from my "Art of Decorative Design" a few remarks on this subject.

This statement can well "be illustrated by the Egyptian and Greek water-vessels, the former of which has sides tapering to the top and slanting inwards, a small orifice, and a rounded base, and the mouth of the vessel bridged by an arched handle, the whole being constructed of bronze (Fig. 84); the latter consists of an egg-shaped body (the broad end being above) resting upon a secure foot, which is surmounted by a large, divergent, funnel-shaped member (Fig. 85). It has no handle over the orifice, but has one at either side.

"Not only do these vessels differ in form, but associated circumstances differ also; and it is this variation in circumstances which brought about the difference in form of the two water-vessels.

"The peculiarities of the Egyptian water-vessel are its formation of bronze, the roundness of its base, which renders it unfit for standing, the narrowness of its mouth, and the handle arching the orifice; and of the Greek, its being wrought in clay, the secure base, the wide mouth, the contraction in the centre, and the handle at either side. We should judge from these vessels that the Egyptians drew water from a river, or some position which required that the vessel be attached to a cord and cast into the source of supply, for the roundness of the base at once points to this, it being a provision for enabling the vessel to fill by turning upon its side (were its base flat it would float on the water); it is also formed out of metal, so as to facilitate this end. The arched handle not only points to the attachment of the vessel to a string in order that it be cast into the water, but also to the carrying the vessel pendent from the hand in the manner that pails are at present carried, and the contracted mouth restrains the splashing over of the water: and what this simple water-vessel points to we find to have been the case, for the Egyptians derived water from the Nile in the very manner that the vessel would indicate; but with the Greeks circumstances were different, as the water-vessel would indicate. The base is here flat, in order that the vessel may stand; the mouth is large, in order to collect the water which fell from above, from the dripping-rocks and water-spouts. This being the manner in which water was gathered, a vessel formed of heavy metal was unnecessary, the contraction pre-

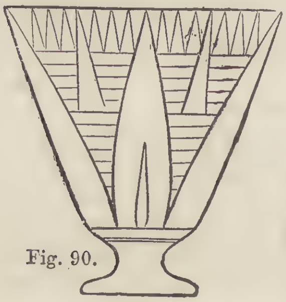


Fig. 90.

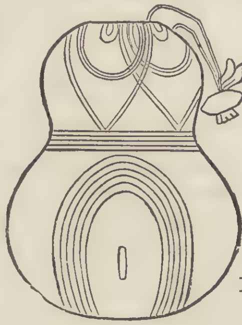


Fig. 82.

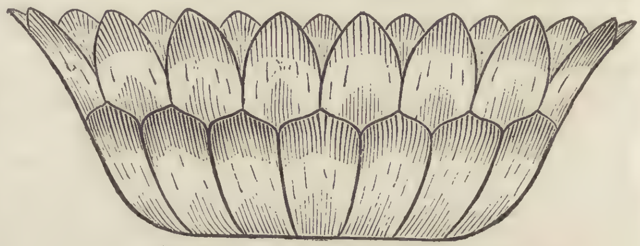


Fig. 91.

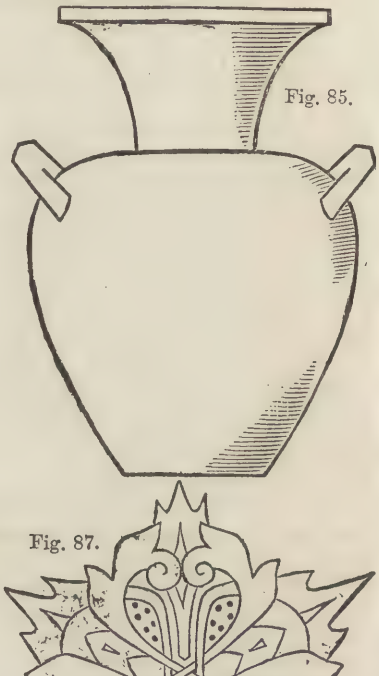


Fig. 85.

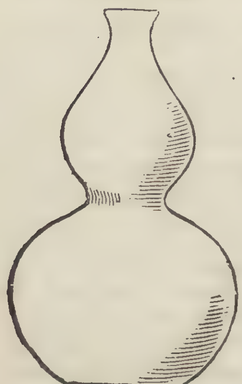


Fig. 83.

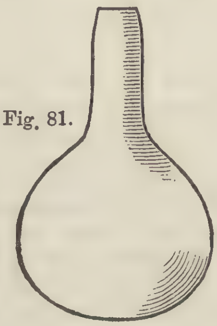


Fig. 81.

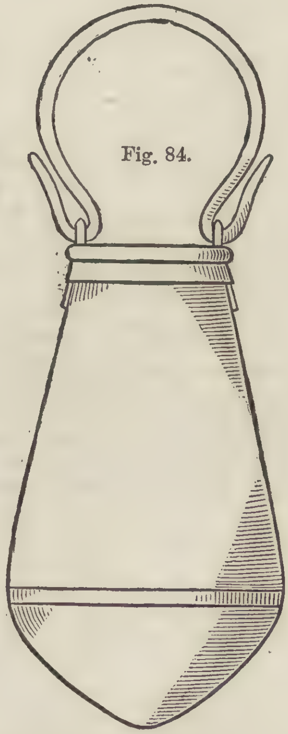


Fig. 84.

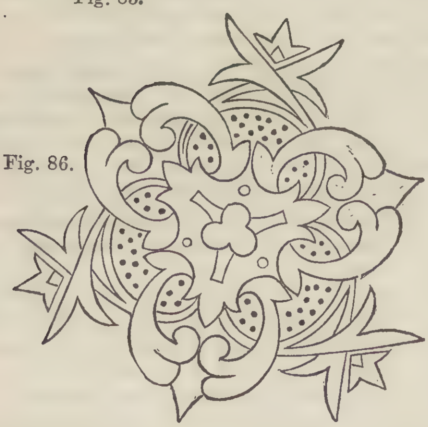


Fig. 86.

Fig. 87.

vented the water from splashing over when carried, and up to this point the vessel was filled, and no higher; and the handles at the sides show that it was carried on the head. But, in conjunction with this mode of carrying, there is another consideration of interest, which is, the centre of gravity was high. If we attempt to balance a stick, having one enlarged end, on the finger, it will be found necessary that the weight be at the top; and in balancing anything, it will be found that the object, in order that it must ride steadily, have its point of greatest weight considerably elevated above its base. In the Greek water-vessel, which was carried balanced on the head, we find this condition fully complied with, the centre of gravity occupying a high position, while in the Egyptian vessel the centre of gravity was low; but where the vessel is to be carried underhand, it is as great an advantage to have the centre of gravity low as it is in the case of a coach, where security is thus gained just as the centre of gravity is lowered. The Greek water-vessel, then, consists of a cavity for holding water, a funnel to collect and guide the water, a base for the vessel to rest upon, and handles to enable it to be raised to the head, and the centre of gravity is high in order that it be readily balanced; and we should judge from this vessel that the Greeks procured water from dripping-rocks and water-spouts, and this is exactly what did occur. These are the direct teachings of the Egyptian and the Greek water-vessels; yet how many circumstances and incidents of common life can be conceived as associated with these different forms of vessel. There is the gossip round the well, and the lingering by the river-side where the image of the date-palm is mirrored by the glassy surface of the waters. The effect of the noise of the splashing water upon the mind in the one case, combined with the comparatively loud and energetic speaking which would be necessary in order that the voice be not drowned by the noise, and of the calm tranquillity of the river-bank in the other, where the limpid water is ever flowing on in silent majesty, must be considerable. Then we have the potter's art essential to the production of the vessel in the one case, and the metal-worker's in the other—the digging of clay, the mining of metal, the kilns and smelting-furnaces. We will not continue this portion of the subject any further, and have brought forward this illustration in order to show how well-considered objects reveal to us the habits and customs of the peoples and nations in which they originated."

Fig. 89.

It will now be apparent that even a common object may result from such careful consideration that its form will at once suggest its use; but the object will only reveal the purpose for which it was created with definiteness of expression when it perfectly answers the end proposed by its formation. The advice which I must give to every designer is to study carefully exactly what is required, before he proceeds to form his ideas of what the object proposed to be created should be like, and then to diligently strive to arrange such a form for it as shall cause it to be perfectly suited to the want which it is intended to meet.

More will be said upon the subject of form when speaking of glass vessels and of silversmiths' work; and when considering these subjects we shall also give the law which governs the application of handles and spouts to vessels, and it is of the utmost importance that they be correctly placed in order that the vessel may be used with convenience. A word must now be said respecting the decoration of earthen vessels, but on this subject our remarks must be brief.

The object to which the decoration is applied must determine the nature of the ornament to be employed. In the case of a vessel which is to be in part hidden when in use great simplicity of treatment should be adopted, and the ornament may with advantage consist of repeated parts. In the case of a plate, little or no ornament should be placed in the centre; but if there is a central ornament it should be a small, regular, radiating figure, consisting of like parts (Figs. 86, 87). The border should also consist of simple members repeated, for it will then look well if portions are covered; and these remarks will apply equally to all kinds of plates, whether intended for use at dinner or dessert.

Fig. 88.

No plate should have a landscape painted upon it, nor a figure, nor a group of flowers. Whatever has a right and wrong way upwards is inappropriate in such a position, as whatever ornament a plate bears should be in all positions as fully right way upwards to the beholder as it can be. Besides, landscapes, groups of flowers, and figures are spoiled if in part hidden, provided they are satisfactory when the whole is seen.

Plates may have a white ground, for it is desirable that those articles on which food is presented should manifest the utmost cleanliness, yet to a cream tint there could be no objection. I should, however, prefer white plates, with a rather deep blue, Indian red, maroon, or brown pattern upon them, and a pale buff table-cloth for them to rest upon.

In the case of cups and saucers the treatment should be similar to that of the plate. The saucer may have a simple border ornament, consisting of parts repeated, and little or no ornament in the central portion on which the cup rests. The cup may have an external border ornament, and a double narrow line of colour around the upper portion of the interior, but no other ornament is here required.

Whatever ornament is placed around a cup, or vase, or any tall object must be such as will not suffer by perspective, for there is scarcely any portion of the ornament that can be seen otherwise than foreshortened. Let simplicity be the ruling principle in the decoration of all rounded objects, and ever remember that a line which is straight on a flat surface becomes a curve on a round surface (see page 327).

I have given what is a correct decoration for a plate and cup and saucer, but there are other methods of treatment than those just named. The Japanese are very fond of placing little circular groups of flowers on plates, saucers, and bowls (Figs. 88, 89). The Greeks had various methods of enriching their tazzas and vases with ornament, and the Egyptians were partial to the plan of rendering a cup as a lotus-flower (Fig. 90). But when they formed a cup thus, they were careful to draw the flower conventionally and ornamentally, and never produced an imitative work. The Chinese treat the flower of the sacred bean in the same way (Fig. 91).

What I have said has been addressed to the student. The remarks, however, made respecting the form chosen being that which is most suitable to the end proposed, and the conditions to which I shall make reference as governing the application of handle and spout to any object, are binding upon all who would produce satisfactory works; but to the genius who has power to produce beautiful and vigorous ornament, and whose taste has, by years of study and cultivation, become refined and judicious, I can give no rules, his own taste being his best guide.

SANITARY ENGINEERING.—X.

WARMING BY HOT WATER.

OUR last paper was occupied by the details of some methods adapted for heating by the circulation of *warm* water—that is, water under the boiling-point, viz., 212°, and open at various points to the atmospheric air. We now propose to deal with another branch of the subject, viz., heating by *hot* water; in this case the temperature is raised much above the boiling-point—indeed, 500° may be taken as a point that has been reached; and the apparatus must therefore necessarily be hermetically sealed, and all communication with the external air carefully prevented. Several systems have been introduced with more or less of success, but the one which has been and is now most extensively in use is that of Mr. A. M. Perkins, which we proceed to describe. In heating by warm water, many and various sizes of boilers may be adopted, and cast-iron pipes of various construction and considerable size are used; but it is evident that these materials are unfitted to withstand the immense pressure generated on this, which is sometimes called, on that account, the high-pressure system. The pipes used are therefore of the very best quality of wrought iron made in Staffordshire, and proved before being sent to London up to about 3,000 lbs. pressure to the square inch. When the system was first introduced, about the year 1830, or a little later, the pipes used were about ½-inch bore, and about ⅞ external diameter; but subsequent practical experience has led to the introduction of pipes of about one inch internal diameter, the friction being thus considerably reduced, and greater freedom of circulation obtained.

A certain proportion, varying according to circumstances, of the total quantity of pipe required for heating purposes, is arranged in the form of a coil, and placed in a furnace constructed for the purpose, thus taking the place of the boiler in the ordinary warm-water apparatus. The size of this coil varies, of course, with the work to be done, from a little affair which may be placed at the back of the grate of an ordinary dwelling-room, to a large apparatus six feet or more in length necessary for warming the various floors of an extensive warehouse or mansion. Coke or hard Welsh coal, which, not being of a bituminous nature, is not liable to clog, is the fuel used in preference, and by means of control in connection with the furnace-doors and dampers in the flues, the heat can be regulated with great nicety. As the expansion of the water under this system increases with the increased temperature, and of course to a much greater degree than with the warm-water system, some special provision for this purpose is required; and this is obtained by fixing at the topmost part of the apparatus an expansion tube generally about four inches in diameter, hermetically sealed and screwed up—it being necessary in some cases to provide for an expansion of 20 per cent. in bulk. A reference to our last paper will show the absolute necessity of this provision, as some apprehension may probably be excited by the high rate of pressure to which the pipes are subject; but on all these subjects practice is the best guide, and the recorded accidents arising from the employment of this method of heating when the work has been properly and scientifically executed are so few, that we have not yet met with one of sufficient importance to be worth recording. There are, however, various points to be especially attended to.

It will readily be seen that a certain portion of the small vacuum remaining when the pipes have been filled with water as the temperature is raised to the figures mentioned above, must be filled with high-pressure steam, and great care is necessary to prevent this steam from accumulating at any one point to such an extent as to cut off the communication or circulation of the water; when this is the case, the result is that, though the circulation may still go on, the opposition offered by the steam is overcome by a series of blows or jumps (resembling in their action the passage of gas through an accumulation of water in gas-pipes, which produces the jumping in the light with which we are all more or less familiar); and in a system of hot-water apparatus, when this occurs, a series of heavy blows or shakes are felt which shake the whole apparatus, and sometimes even the building to which it is applied.

The great secret of the successful application of the system is to conduct the water from the coil, in which it is heated, at once to the highest point at which the apparatus is required to work, and from thence to bring it down through the various floors and different levels with intermediate coils or without, as the case may require, until it again re-enters the heating coil at the bottom, and the circulation is complete. Any attempt to reascend—*i.e.*, within the circuit of the apparatus to supply a higher level from a lower one, supposing them to be both at an intermediate distance between the furnace-pipe at the bottom and the expansion-pipe at the top—is attended with this risk, that at some point in the pipe an accumulation of steam may occur with the disagreeable result above indicated. Another objection sometimes urged against the system is that the quality of the air heated by iron at so high a temperature is deteriorated, and therefore unhealthy; but here again the record of facts is on the other side, and the great number of gentlemen's mansions and other public buildings in which it has been employed are a sufficient answer to the objection. The reason probably being that the heating surface being small and the temperature high, such a constant current is maintained, that the change of air in immediate contact with the pipes is too rapid to allow of any injurious effect resulting.

Having then generally described the construction of the *hot-water* apparatus as distinguished from the *warm*, we will proceed to give a few instances of its practical application, remarking that the small size of the pipes affords great convenience for their introduction into all parts of dwelling-houses in a concealed form—*e.g.*, they can be carried between floor and ceiling, and the heat admitted into the room above by small openings or ornamental iron gratings as may be most desirable. They may also be introduced in various combinations—a single pipe all round the room, behind the skirting, or along one side only, or a double pipe in a similar direction. A room may also be efficiently heated by a coil in one corner, which may be arranged so as to resemble a table, and be covered with a marble slab; or in case there is a fire-place in the room which has been superseded by the introduction of the hot water, a coil of pipe can be placed therein, and if made a portion of a carefully-arranged system, the room will be efficiently heated.

We now give a few examples of well-known public buildings which have been at various times heated by this method—some of them have since been subjected to alterations for various reasons unconnected with their warming; but as they are only quoted as examples of what work has been done and results attained, this does not in any way affect the question at issue. To commence with a very small apparatus, two small rooms connected with a well-known public office, one about eleven feet, and one about nine feet square, were warmed by about sixty feet of pipe, a small coil being fixed at the back of the grate in the smaller room, and heated by the ordinary fire. The expansion and filling pipes were at the side of the fire-place. These rooms were inspected by a professional gentleman, when the temperature of the external air was 40°. In the larger room the thermometer stood at 56°, and the pipes were so cool as to bear the hand, the apparatus being very slightly worked. On the coldest day in winter, with the glass down to 20°, the temperature was 50° with the usual fire.

We now propose to describe a well-known warehouse in Edinburgh where an apparatus on a more extensive scale was introduced. The building, an extensive one, consisted of a basement occupied by cellars, in one of which the furnace was erected, a ground-floor used as a packing warehouse; the principals' and clerks' offices on the first floor; a sheet warehouse on the second floor, and a third floor used by bookbinders. The flow-pipe was taken direct from the basement up to the bookbinders' room, and here the expansion-pipe was fixed, this topmost floor being heated by two pipes running all round along the walls. Two pipes then were taken down through the sheet warehouse on the second floor, where no artificial warmth was required, and communicated with two coils, one in the private, and the other in the general office. Thence the pipes were led down to the ground-floor, where a single coil was placed, and from this the return pipe re-entered the furnace; the total length of pipe being about 1,000 feet. The daily consumption of fuel was about three-quarters of a cwt., one-third coal, and two-thirds coke; and this is a point worth remark—the fire office charged the warehouse only at ordinary dwelling-house rates. Nor is this a solitary instance, as with proper precautions taken, and the necessary requirements of metropolitan and local building acts properly complied with, it is recognised among those commercially interested in the question that no extra rate of insurance is charged for the introduction of this method of heating. The system has been extensively used for horticultural purposes, and it presents this advantage, that by having more than one range of pipes around a vinery or hot-house, it is possible by means of stopcocks to regulate the amount of heat to the temperature of the day, whatever it may be; the power of the apparatus being such, that when in full operation, the building may at any time be raised the requisite number of degrees above the temperature of the external air.

The number of residences, mansions, banks, and warehouses where it is in satisfactory operation are exceedingly numerous: and as recent instances of its introduction within the limits of the last few months, we may mention an extensive and lofty paper warehouse built last year for Messrs. Spicer in Thames Street; the new hall at the Bow station, with refreshment rooms and offices attached; and, as a rather unusual application of the principle, the first-class carriage shed upon the same line. The effect of atmospheric influence in our damp climate upon the cloth, leather, and other materials necessary for the fitting of first-class carriages, unprotected by artificial warmth, will be readily understood to be detrimental; but the results of the working of the apparatus, which our space will not allow us to describe in detail, are reported as thoroughly efficient. We may mention in passing, that portions of Buckingham Palace and Marlborough House are fitted with an apparatus of similar character modified to meet the requirements of different departments in some portions of the buildings.

The principle is capable of extended application to all trade purposes—for drying-rooms of every description where a high temperature is required; for breweries, where an equable heat is desirable in all conditions of the weather. One, however, of its most recent adaptations merits more than a passing notice: it has recently been used in the construction of patent portable ovens for military purposes in the field, and bread can be baked in these as perfectly and as cheaply as in an ordinary baker's oven. The construction is very peculiar: a long segment-headed, double wrought-iron case is arranged in a compact form upon four wheels, the space between the cases being filled with a non-conducting material, that called vegetable black being used in preference. In the interior, the bottom, and also the top of the oven consist of rows of pipes a short distance from each other, and projecting beyond the oven into the furnace, which is contained within the external casing, and is lined with fire-brick, and lighted with coke. There is no inter-communication between the pipes, those forming the bottom of the oven are slightly inclined, and the circulation or flow and return of the water proceeds in each pipe in itself. A lamp fixed on the end at one side throws a light into the interior, and a glass lens enables the *baker* to watch the loaves in process of baking, and carefully regulate their progress. Between thirty and forty in number of these ovens are now in use in the English army at various stations, and their introduction will doubtless be more extensive.

The great recommendation of the general process, however, in its application to all the ordinary requirements of domestic and commercial purposes, is the small space required for the pipes, and the great variety of ways in which they can be adapted and grouped to meet almost any set of circumstances. As atmospheric air is carefully excluded, no evaporation takes place, and the waste in the water employed is consequently almost inappreciable. Systems have been at work for several years without requiring any attention; the only change noticed after a considerable interval being a certain darkening in colour of the water when removed. It is necessary to take every precaution before the apparatus is first set at work to ensure the perfect soundness at every part. We have already mentioned the severe test applied to the pipes in the first instance, and it is usual before lighting a fire in the furnace, or under the coil, as the case may be, to subject the whole, as fixed *in situ*, to a powerful hydraulic test, which inevitably discovers any weak part of joint; and this having been carefully done when the result is satisfactory, it may be taken for granted that with ordinary care in the daily working, it will be perfectly efficient for many years.

In our succeeding paper we shall take up the detail of steam and hot air, as applied to a similar set of conditions as those before described for warm water in our last, and hot water in the present paper.

OBJECT DRAWING.—XII.

MODEL MAKING (*continued*).

Possibly from the instructions given for making a cube in the last lesson, as well as those for constructing from a flat sheet of cardboard a rectangular oblong, generally called a parallelopiped, our readers, or such of them as may have chosen to try their 'prentice hand at this kind of work, have succeeded in turning out strong and well-shaped models of the solids which we have just named, suitable in every respect for affording practice in the art of object drawing.

We shall presently proceed to give detailed instructions for the construction of models of other solids, some as simple as those which we have already described, while others will be found to be more complicated in form, and demanding great nicety and exactness in construction, and considerable carefulness in manipulation. But before entering on the more practical business of the lesson, let us pause awhile, and endeavour to show the learner how this model making may proceed from the construction of objects of simple form to others of more elaborate shape and multiplicity of detail. For the encouragement of those who, emboldened by their first success in the construction of a cube and parallelopiped, are anxious to proceed to the making of objects possessing greater variety and intricacy of form, we may point out that the rough method employed is the same, or very nearly so, in all cases—that the plane surfaces forming any solid object, whatever its form may be, and even the curved superficies which enter into the construction of many, may be projected on a flat surface of a single sheet of cardboard, and afterwards joined up into the form of the solid by means of strips of cardboard projecting beyond the outline of the surface or surfaces required, as shown in our last lesson in the construction of the cube and parallelopiped.

Modelling in cardboard is more especially applicable to the building arts; but although there may be more difficulty in producing such objects as carriages, etc., from the curvature of some of the surfaces which combine to form their exterior superficies, there is scarcely one of the constructive arts into which this beautiful art cannot be introduced or adapted, and brought into use with advantage both for the maker and those for whose pleasure or information the model may be made. For architectural work of any kind modelling in card is available, and all projections, such as string courses, mouldings, labels over windows, the ornamental woodwork or barge-boards in the gables of Gothic buildings, etc., etc., may be shown with the utmost facility by methods that will readily suggest themselves. In what we have just advanced, that modelling in card may be used with advantage for the maker as well as for those for whom the model is made, we may prove the truth of our assertion by a single example. There are not many who can readily conceive what may be the appearance that a building will

ultimately present when placed before them in elevation and section on the flat surface of a piece of paper. To the architect or builder, as well as the workmen who are to be employed in its construction, the surface drawings give as clear an indication of what the building will be when completed, as a model of it constructed according to scale. In the case of a lodge, for instance, at a park entrance-gate, how much more readily could the owner of the park decide on the style of building he

cutting each other in C. Draw A C and C B, which will complete the triangle.

It may be well in this place to remind the student that a triangle in which only two of the sides are equal is called an *isosceles* triangle, as Fig. 68.

When all three sides are of different lengths the figure is called a *scalene* triangle, as Fig. 69. In a right-angled triangle (Fig. 70) one of the angles, as C, is a right angle.

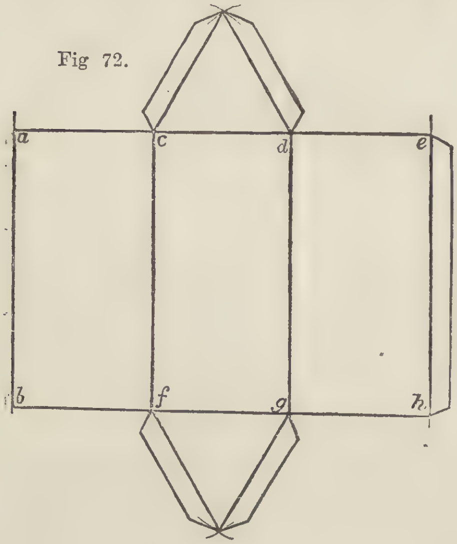


Fig 72.


Fig. 69.

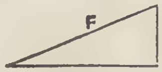


Fig. 71.

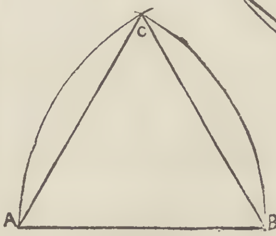


Fig. 67.

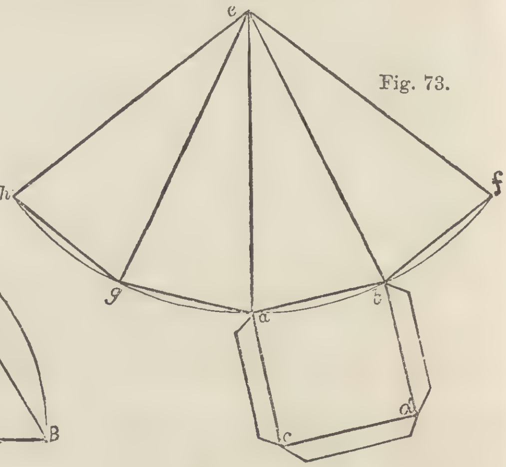


Fig. 73.

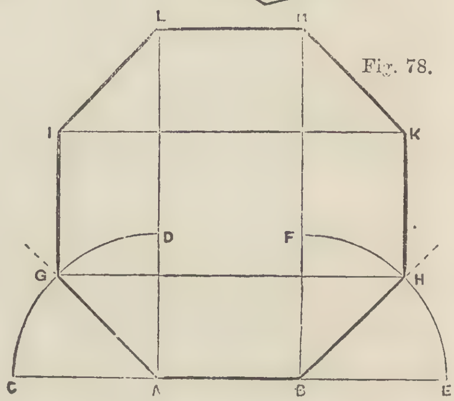


Fig. 78.

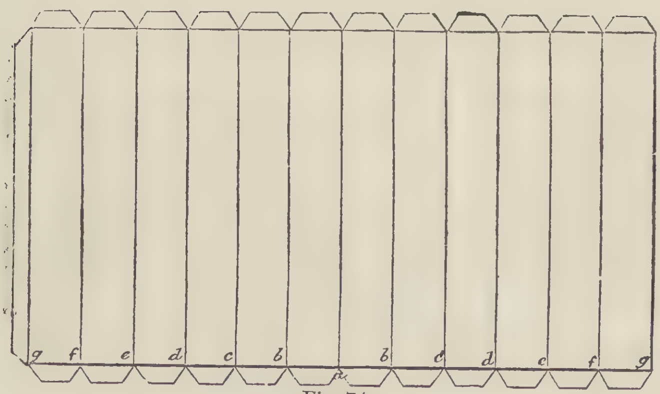


Fig. 74.

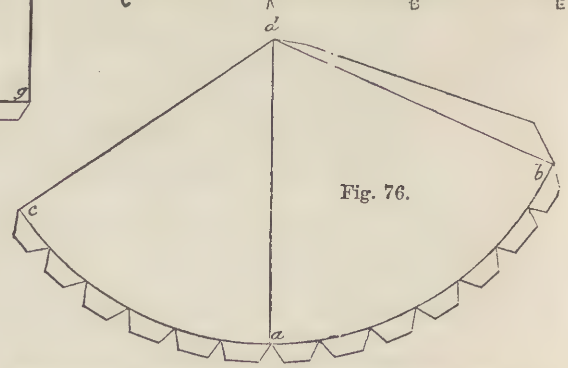


Fig. 76.

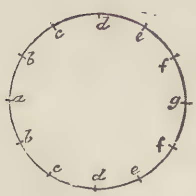


Fig. 75.


Fig. 68.

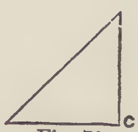


Fig. 70.

would wish to be placed there, if two or three models could be put before him, instead of drawings in the flat. It is, however, time to return to the main subject before us, and in the present lesson we will first show how—

To construct a triangular prism, the sides being equal.

This object consists of two equilateral triangles which constitute the ends of the prism, and three rectangles, the width of which is equal to the side of the triangle.

Let us, in the first place, remind the student of the method of constructing an equilateral triangle.

A B (Fig. 67) is the given side.

From A and B, with the length (or *radius*) A B, describe arcs

A right-angled triangle may be either isosceles, as Fig. 70, in which two of the sides are equal, or it may be scalene, as Fig. 71, in which the sides are of different lengths. The longest side of a right-angled triangle, as F (Fig. 71), is called the *hypothenuse*.

Now to commence the prism (Fig. 72). Draw the line $a\,b$ equal to the required length, and at each extremity draw lines at right angles to it.

On these lines set off from a, $a\,c$, $c\,d$, and $d\,e$ equal to the width of the sides, and from b set off the same lengths, $b\,f$, $f\,g$, and $g\,h$.

Draw $c\,f$, $d\,g$, and $e\,h$, which will complete the sides.

Now, on $c\,d$ and $f\,g$ construct equilateral triangles, leaving

strips at the edges for attachment of the sides. Cut half through the inner lines, and entirely through the outer ones, and, having turned the figure, the sides and ends are to be bent up and gummed or glued together.

Fig. 73 is the development of a square pyramid.

Construct the square *a b d c* for the base.

From *a* and *b*, with the length of the slanting edge of the pyramid, describe arcs, cutting each other in *e*.

Draw *e a* and *e b*, thus forming an isosceles triangle.

Now, from *e*, with the radius* *e a*, draw an arc, and on it set off *b f*, *a g*, *g h*. Join these points by straight lines; leave the necessary margins for attachment; cut the lines either half or entirely through as required, and complete the figure.

To construct a cylinder (Fig. 74).

With the required radius describe the circle which is to form one of the ends. (It will, of course, be understood that two such will be necessary.)

Now it will be perfectly clear, even to the most casual observer, that when any cylindrical surface is unrolled it becomes a parallelogram; for any sheet of paper, when rolled up, becomes a cylinder. The question, then, to be solved is, what size must the rectangle be so that when rolled it may form a cylinder of the required diameter. To accomplish the result which may answer this question—

Divide the circle (Fig. 75) which is to form one end of the cylinder into any number of equal parts; and it must here be explained that the greater the number of these parts the better; for it will be clear that if these points were joined by straight lines, the straight lines would be slightly shorter than the curve; and thus the greater the number of points the less will that difference be.

In the present example, which is intended only to show the method of construction, the circle is divided into twelve parts; but this would not in practice be found sufficient for a cylinder of any useful size, and the student is therefore advised to divide it into twice or thrice that number.

Draw the horizontal line *a*, and on each side of any starting-point as *a*, set off the divisions *b*, *c*, *d*, *e*, *f*, *g*. At *g*, *g* erect perpendiculars equal to the length of the cylinder. Join these by a horizontal line, and the rectangle thus formed will be the surface which, when rolled around the circular end, will give the required form.

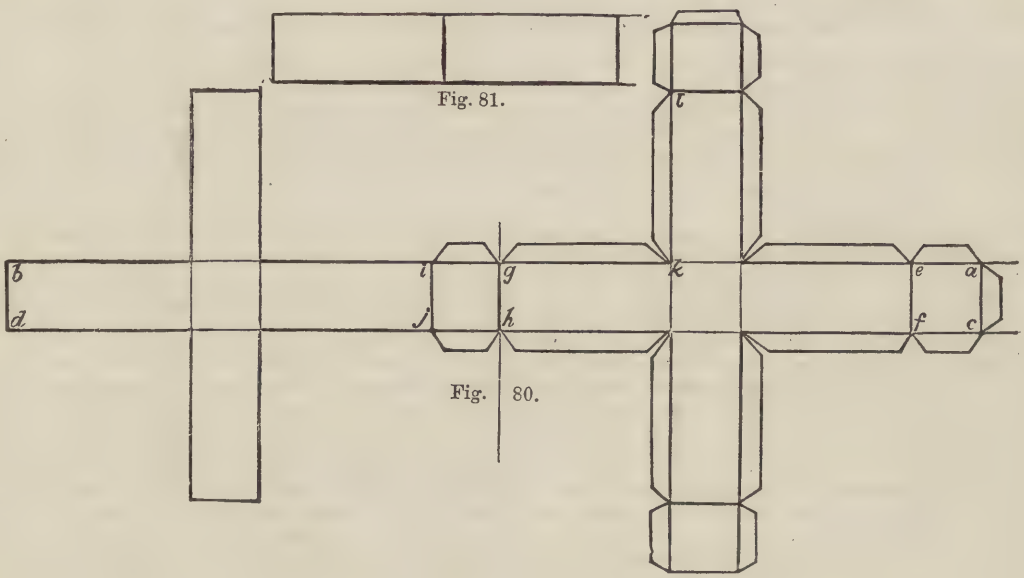
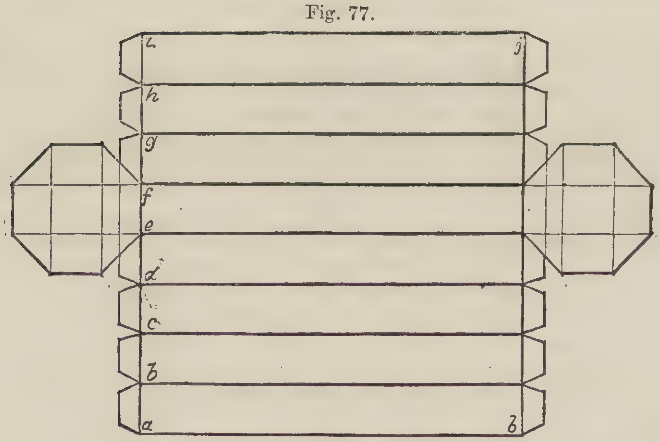


Fig. 81.

Fig. 80.

Fig. 77.



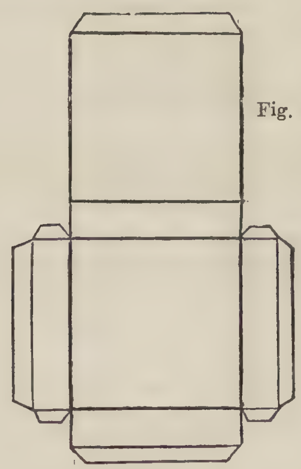


Fig. 79.

* The *radius* is the length from the centre of a circle to the circumference; it is, in fact, the distance between the two points of the compass when describing a circle. Thus, if it were said, "With a radius of three inches," it would mean, open your compass to the distance of three inches.

Of course it must be remembered, as in some of the models we have already given, that margins must be left at the top and bottom of the rectangle by which the circular ends may be attached to it.

One word as to the proper making of this object. When the two circles constituting the ends are made, and when the rectangle of its full size has been cut, this should be rolled up on a round stick or roller as closely as can be, like a roll of paper. This should be done again and again, so that the surface may become perfectly cylindrical, and may not, from the very strength of the cardboard, burst open, although they are glued together.

Another good plan is (when the rectangle has been cut, and when the edges have been glued together, the edges having been previously shaved down with a sharp knife, and the margin having been split) to tie a thread around it during drying, in order to keep the cylindrical portion in shape, and to prevent its expanding during drying.

This should be allowed to wait a little, so as to become firm before being affixed to the circular ends.

Fig. 76 is the development of a cone having a base equal to either end of the cylinder. This should fit upon the cylinder, and thus the same circle (Fig. 75) which formed the ends of the cylinder may be used as the base of the cone.

Draw a line $a\ d$ equal to the length of the slanting side of the cone, and with this length as a radius, describe an arc. On this set off on each side of a the several divisions of the circle—viz., to b and c. Draw $d\ b$ and $d\ c$, which will complete the development of the cone. The necessary margin having been left, roll the shape, and attach the edges $b\ d$ and $b\ c$; and the base having been prepared, the parts are to be fastened together, thus completing the object.

Fig. 77 is the development of an octagonal prism, and we must therefore, in the first place, construct an octagon on a given line, A B (Fig. 78).

Produce A B on each side, and erect perpendiculars at A and B.

From A and B, with radius A B, describe the quadrants C D and E F.

Bisect these quadrants (that is, divide each into two equal parts), viz., in G and H.

Draw A G and B H, which will be two sides of the octagon.

At H and G draw perpendiculars, G I and H K, equal to A B.

Draw the horizontals G H and I K.

Make the perpendiculars A and B equal to G H or I K—viz., A L and B M.

Draw I L, L M, and M K, which will complete the octagon.

Now to make the prism (Fig. 77), draw the line $a\ b$ equal to the length of the intended prism, and draw a perpendicular at each end of it.

From a set off b, c, d, e, f, g, h, i, equal to the side of the octagon, and draw lines across; then the rectangle $a\ i\ j\ b$ will be the development of the surface of the prism.

At each end of one of the sides, as $e\,f$, construct an octagon, and leave margins on the edges of the rectangle, which will complete the entire figure.

When the whole has been cut out, the lines b, c, d, etc., are to be cut half through, so that the card may bend at the angles as required.

Fig. 79 is the development of one of the square slabs shown in previous lessons, and as this is to be constructed in a manner precisely similar to the cube, the proportions of the sides only being varied, no further explanation will be found necessary. The low pyramid shown in Fig. 24, is also constructed like that in Fig. 44, the sides being formed of four equilateral triangles.

The object to be next constructed (Fig. 80) is a cross. The geometrical form of this will be easily understood. Draw the lines for the horizontal bar, $a\ b$, $c\ d$ of each side. Set off on these from a the width of the square end, $a\ e\ f\ c$, of the whole cross, of the other square end, $g\ i\ j\ h$, and of the cross again. Draw the upright bar on each, and the square ends at top and bottom of one of these, leaving the margins for attachment. The strip (Fig. 81) will then be required to fill in the sides of the right angles at $g\ k\ l$. The mode of finishing will now be obvious. The six-armed cross, shown in Fig. 53, should be made of wood, and will be understood from the separate parts given in Figs. 47, 48, 49, and 50.

CIVIL ENGINEERING.—XI.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DOCKS (*continued*).

HAVING considered the character of *excavated* dry docks, we shall now direct attention to other means of obtaining access to the exterior of a vessel—namely, by lifting the ship out of the water. These may be divided into two classes—1st, that in which the vessel is raised vertically out of the water, by either hydraulic power, or by placing under it another vessel having the power of floating or sinking at will; and, 2nd, that in which the vessel is drawn out of the water by means of an inclined plane. The means employed in these two cases are obviously of a character sufficiently diverse to warrant their having independent positions assigned them in our notice of the subject; indeed, the first division is itself susceptible of being subdivided, and the hydraulic lift graving-dock will occupy our attention in the first place.

It is obvious that all that is required in order to raise a vessel vertically out of the water is that there shall be a proper hold taken of the ship, so that it shall not be subjected to strain in the act, and that there shall be sufficient power available for the purpose; and we might add that, having been raised from the water, there shall be prepared a proper stage on which the vessel shall rest whilst undergoing repairs. The entire question of how best to dock a vessel for repairing must, after all, rest upon the matter of expense. Without doubt, the most natural method is that of floating the ship quietly into a basin, and, having properly arranged the necessary supports, simply to withdraw the water, and leave her high and dry; but when we regard the immense cost of a regularly excavated dry-dock, and remember that such a dock is available for one vessel only at a time, and that her repairs may occupy many days, perhaps weeks, we see at once that, looked at simply in a commercial point of view, the interest upon the outlay must be exceedingly limited, unless, indeed, an almost prohibitory scale of charges be made for the use of the dock. Hence it arises that other means have been suggested for obtaining the desired object.

The amount of power obtainable by means of hydraulic pressure is almost unlimited; and we have, therefore, only to apply the power in the proper direction in order to secure all that is needed for our purpose as to raising the vessel. The vessel being thus raised, and suspended as it were over the water, it then remains to introduce beneath it another and specially constructed vessel, having in itself sufficient buoyancy to float both itself and the vessel lowered upon it. This, with its burden, being then floated away, the hydraulic apparatus becomes at once available for another hoist. Such, then, is the general character of a hydraulic lift dock; and we shall now proceed to explain its action in detail.

The "lift" is a direct mechanical appliance for raising the vessel by means of hydraulic presses. It consists of a number of hollow columns ranged in two parallel rows, the rows being placed at such a distance from each other as that the largest vessel it is intended to raise shall be able to pass between them. The columns are firmly bedded into the soil, and, for greater security, are connected together at the top by a framed platform of wrought iron, each row being, of course, an independent structure. Inside each column is fixed a press, whose base is bedded upon concrete, with which each column is filled up to that point.

In the case of the hydraulic lift graving-docks in connection with the Victoria (London) Docks, at Blackwall, the columns are 68 feet 6 inches long, being bedded 12 feet in the soil. They are taper, being 5 feet in diameter at the base, and 4 feet in diameter at the ground-level, from which point upwards they are parallel. There is a clear space of 60 feet between the two rows, and the columns are placed 20 feet apart, from centre to centre, and stand on each side of an excavated pit, in about 27 feet of water. There are 16 columns in each row, giving $16 \times 20 = 320$ feet of length from end to end; but as it is not necessary that a vessel stand entirely within this length whilst being lifted, it is practicable to raise a ship of 350 feet length at these docks. The concrete upon which the presses rest is covered with a layer of 2-inch plank, to act as a cushion for the cast-iron seat of the press.

We show in Fig. 20 a section of one of the columns with the included press. C C represents the column, P P the press, and R R the ram. X X is a cross-head, 7 feet 6 inches long, made

of boiler-plate, projecting 1 foot 9 inches beyond the column on each side, and working in a vertical slot in the column, which thus acts as a guide for the ram. The ram, R, is 10 inches in diameter, and has a stroke of 25 feet clear, and the cylinder enclosing it is retained in the centre of the column by boiler-plate diaphragms, D D, resting, as we have said, by its cast-iron base upon a bed of concrete, with a 2-inch slab of wood between the hard surfaces. To the projecting ends of the cross-head, X X, are attached wrought-iron bars, B B, which support two iron girders, G G, each 65 feet long, which extend entirely across the dock to the corresponding column, and press on the opposite side. There are thus sixteen pairs of suspended girders, which when the rams are down lie at the bottom of the water, but rise with the rams above the surface when required. These sixteen pairs of girders form together a large wrought-iron platform, which can be raised or lowered at pleasure, with a ship upon it. The girders are 5 feet 9 inches deep, of wrought iron, trussed with a cast-iron top-flange.

The pontoons—one of which is floated over the sunk girders, and, by the admission of water, sunk with them to the bottom of the dock, ready for the vessel which it is intended to raise to be brought over it—vary in dimensions with the size of the vessel which is to be placed upon them. Their width is uniform, being somewhat less than the clear space between the columns, but they vary in length and depth according to requirement. They are constructed of iron, having vertical sides, and strengthened both longitudinally and transversely by wrought-iron girders, running from end to end, and from side to side, and thus dividing the entire pontoon into a series of rectangular divisions. These divisions serve the additional purpose of dividing the pontoon into several water-tight compartments, each compartment being furnished with a valve, V, in the bottom (Fig. 21).

In Figs. 21 and 22 we show a pontoon in plan and elevation. The pontoons are open at the top; the transverse girders are 8 feet apart, and support the keel and bilge-blocks on their upper flanges. In some pontoons the transverse girders slope slightly towards the centre, to facilitate the running in of the block-frames. The central longitudinal girder is made stronger than the adjoining ones, and has a broader top-flange, the better to support the keel-blocks. The depths of the pontoons usually vary from 5 to 7 feet, and their tonnage from 1,000 to 3,000 tons, costing from £4,000 to nearly £11,000 each. The mode of operation is as follows:—A pontoon is selected of a size and tonnage suitable for the ship to be raised, and is floated over the sunk cross-girders; the valves in it are then opened, and the pontoon sunk upon the girders, and the whole gradually lowered to the bottom of the dock. The ship to be raised is then brought between the two rows of columns, and securely moored over the centre of the pontoon. The girders are then gradually raised until the keel-blocks are brought to bear under the keel of the vessel. The side or bilge-blocks are next hauled in by means of chains laid for the purpose on each side of the dock, and the girders and pontoon, with the vessel resting upon it, all raised clear of the water by the presses. The pontoon soon empties itself of water by the bottom valves, which are then closed, and the girders being again lowered to the bottom, the vessel remains resting upon the pontoon, which is then floated away, whilst the deep dock is at once available for another pontoon and ship. The operation of raising a vessel and placing it upon a floating pontoon usually occupies from 30 to 50 minutes.

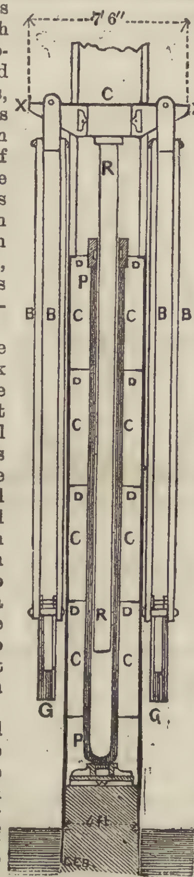


Fig. 20.

In Fig. 23 we show a vessel resting upon a floating pontoon. P is the end of the pontoon, L L the line of flotation, and B B the bilge-blocks, which retain the vessel in her upright position.

The arrangement of the hydraulic valves is one requiring great attention. It must be borne in mind that when a vessel is resting evenly upon all her bearing-blocks, and each block is bearing its proper proportion of weight, yet having regard to the entire mass, there will of necessity be a disproportionate weight at one end or the other, and, to a less though certain extent, at one side than the other. Now when a vessel is floating, she finds her proper line of flotation, and her centre of gravity remaining the same, she will of necessity, even after movement, revert to her normal position. But when her weight is transferred to another rigid floating body, and especially to a body shaped like a pontoon, any considerable preponderance of weight to one end or another causes a risk of her not standing vertically. The advantage of the water-tight compartments thus becomes evident, as by the introduction of water at the more elevated end a perfect level can be ensured.

It is, however, in the act of raising the ship by the presses that the necessity of caution in the arrangement of the hydraulic valves becomes greatest. Suppose the pressure-pumps communicated simultaneously with all the presses, it is evident that the slightest excess of weight at any part of the platform would lower that part, the water passing back through the pipes to the presses where less pressure existed; and the same difficulty would be experienced with two groups of presses, however arranged. Again, if each press were worked entirely independent of one another, it is evident that, to avoid unequal strain, precisely the same quantity of water must be thrown into each press.

The difficulty is, however, entirely overcome, and stability secured, by arranging the presses in *three* groups. These groups are as follow:—Eight adjoining presses at one extremity of the row and the eight opposite presses form one group; eight adjoining presses at the other extremity of a row form a second group; and the eight presses opposite to the second group form the third group. The presses in each group are all connected, and the position of the three groups thus forms a tripod support upon which the pontoon rests; and as each of the three groups of presses can be raised or lowered independently of the other, a

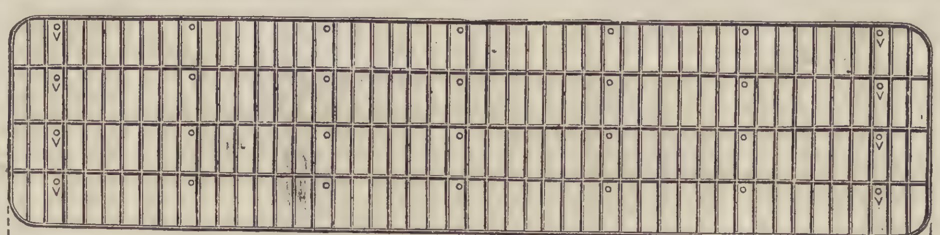


Fig. 21.

PLAN.

Fig. 22.

ELEVATION.

perfect level can be maintained throughout the whole operation of lifting.

The force-pumps at the Victoria Graving Docks are $1\frac{7}{8}$ inches diameter, and are twelve in number, worked by a 50 horse-power engine, six pumps being appropriated to the larger group of presses, and three to each of the smaller. If desired, any of the pumps can be cut off, and thus more power can be applied to the remainder. The presses and pumps were tested to $2\frac{1}{2}$ tons per circular inch; the employment of 2 tons per circular inch applied to the whole of the presses being sufficient to raise a weight of 6,400 tons, of which the rams, cross-heads, chains, and girders occupy 620 tons, leaving available for the pontoon and vessel 5,780 tons, an amount of lifting power greatly in excess of the tonnage of the largest pontoon, and capable of being raised, by increasing the pressure, 25 per cent. The cost of this arrangement will compare exceedingly favourably with that of many excavated stone graving-docks.

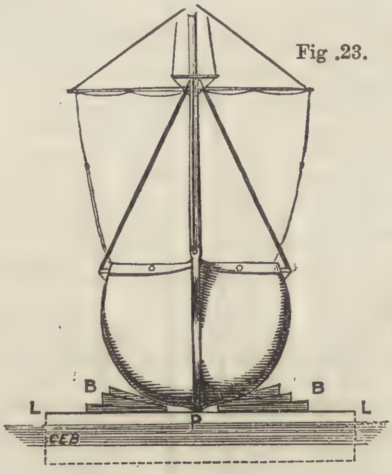


Fig .23.

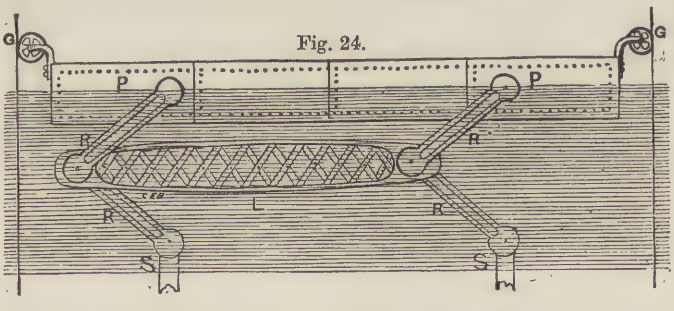
Taking the case of the particular docks we have described, their cost was as follows:—The lift complete and fixed, including columns, presses, girders, pipes, and steam-engine, with all necessary pumps, boilers, and valves, £45,400. This is in reality all that is needed for raising and keeping raised a vessel of 5,000 tons burthen and 350 feet length, and may, therefore, compare directly with the cost of a graving-dock capable of accommodating a ship of similar dimensions; and the large dock at New York, described in our last paper, gives us a fair case for comparison. This, it will be remembered, cost £450,000, and can only dock a vessel of 350 feet length. When, however, we take into consideration the fact that, by the comparatively very small additional cost of a pontoon, a vessel having been raised can be deposited thereon, floated away for repairs, and the lift be made at once available for repairing a second vessel of similar dimensions, and so on for any number, by the mere increase in the number of pontoons, we are better able to estimate the commercial value of this mode of dry-docking vessels. In a mechanical point of view the system will compare equally favourably. In the case before us there is an aggregate pumping-area of 42 circular inches, expanding into a press-area of 3,200 circular inches, rendering the case identical with a lever whose arms are respectively 42 and 3,200, having the power of a 50 horse-power engine on the long end, and the vessel being lifted upon the short end. In an excavated dry-dock there is no advantage gained in the matter of leverage, the work done being direct, and the amount of water to be removed being immensely in excess of what has to be supplied in the hydraulic arrangement. The amount of water distributed under pressure of 2 tons per inch is for the entire hoist 436 cubic feet, whilst the water-area of the United States dry-dock at New York is 610,000 cubic feet, requiring $2\frac{1}{2}$ hours for its removal. The average cost of lifting a vessel and placing her upon a pontoon is only £3, and occupies less than one hour in the operation.

The next form of dry-dock, as being the nearest allied in character to the kind we have just described, is that known as the floating-dock. It is true that pontoons, when employed in connection with an hydraulic lift dock, are in reality floating-docks, but the kind we shall describe differ essentially from these pontoons in the manner in which the vessels are placed upon them. The pontoons we have alluded to merely serve the purpose of supporting the vessels already raised, whereas a floating-dock not only supports a vessel, but raises it as well.

One of the earliest records of a floating-dock we have dates from the year 1776, in which year a shipwright, named Aldersley, constructed a floating-dock of timber in the Thames, which was used for the repair of vessels. Mention is made of another constructed by Watson, in 1785. He constructed his dock with an end-gate, which being lowered to admit a vessel was afterwards raised, and the water pumped out of the dock. It is, however, stated that even prior to these dates—in fact, about the time of Peter the Great—a North-country captain, in the Bay of Cronstadt, wishing to repair his vessel, found an old hulk floating in the bay, and arranged means for letting in and pumping out the water, so as to form a floating-dock. The name of the hulk was the *Camel;* and to the present day a contrivance for raising and lowering weights in the water by attaching them to water-tight iron or wooden boxes, which can be emptied or filled with water at pleasure, is in frequent use by engineers, the box being called a "camel." Sunken vessels are repeatedly raised by the attachment of camels.

The essential characteristics of a floating-dock are—1st, that it shall be possessed of sufficient buoyancy, when required, to float both itself and the vessel placed upon it; 2nd, that its construction shall ensure its stability when floating, both with and without its load; and, 3rd, that it shall be sufficiently rigid in construction to afford efficient support to the enclosed vessel at all points, assimilating itself in the latter respect to a stone graving-dock. The principle upon which the necessary buoyancy is obtained we have already stated, but the mode of applying it varies. A floating-dock of a peculiarly novel character was attempted some years since in the London Docks. A shallow pontoon was constructed of iron, having a closed deck, and capable of being emptied or filled with water by a steam-pump. As the water was pumped out—or, rather, as air was introduced, expelling the water—the pontoon rose; and to ensure its maintaining a horizontal deck in the act of rising, it was connected with the bottom of the dock by a system of side-girders and levers, very similar in appearance to an ordinary double parallel ruler, as shown in Fig. 24. In this diagram P P is the pontoon, G G side-guides at the four corners, to prevent motion of the pontoon endways or laterally, and L a lattice-work girder upon each side, possessing lightness and strength combined; R R are levers of precisely equal length between their centres, connected together by the parallel girder, and securely fixed by screw-piles, S S, or otherwise, to the bottom of the dock. It is obvious that by such an arrangement perfect parallelism is secured. Unfortunately for the success of the experiment, due care had not been taken in the construction of the pontoon by the insertion of bulkheads, whereby the tendency of the water to rush unduly to one end or side would have been prevented; and, as a consequence of this omission, the least excess of water to one side producing a slight depression of the pontoon, the whole mass of water immediately flowed to the lower level, the side-girders and levers becoming so strained as to be unable to perform their functions. The pontoon then tilted, and settled to the bottom, where it remains to the present day, in spite of every effort to raise it. It was hoped, by rapid pumping, to create sufficient buoyancy to bring the pontoon to the surface for repairs and alteration, but 66 tons of water removed per minute had no effect; and when subsequently air in large quantities was forced down into it, her deck blew up, and further attempts were abandoned.

Fig. 24.



SHIP-BUILDING.—I.

BY W. H. WHITE,

Fellow of the Royal School of Naval Architecture, and Member of the Institution of Naval Architects.

INTRODUCTION—EARLY ATTEMPTS—CORACLE—ROMAN GALLEY—GENERAL PRINCIPLES OF SHIPS BUILT OF WOOD—IRON SHIPS—CLASSES OF SHIPS AND DIFFERENCES IN THEIR STRUCTURAL ARRANGEMENTS.

NAVAL architecture may be fairly subdivided into two great branches—ship-design and ship-construction. The former is that which engages the attention of the "naval architect," using that term in the popular sense; and it includes all the work that has to be done in fixing the form and dimensions, calculating the weight, the speed, and other particulars, and predicting the probable qualities of vessels before they are put upon the stocks. The latter—ship-construction or ship-building—is the work of the ship-builder, whose duty it is, when furnished with the drawings, etc., prepared by the naval architect, to carry out in practice the design therein contained. The ship-builder, therefore, stands much in the same relation to the naval architect that the builder on land does to the civil architect; and although a man may be both a naval architect and a ship-builder, he has in this double capacity to perform two distinct sets of duties, each of which requires special training.

Ship-building proper is the branch which the present series of papers is intended to illustrate, and but few references will be made to ship-design. Our hope and aim will be to render intelligible the great principles which should govern ship-construction, and to show to what extent the arrangements commonly adopted are in accordance with those principles. Descriptions will also be given of the more important parts of the structures of different classes of ships, but into the full details of the practical work of ship-building it will be impossible to enter within the limited space at our disposal. This fact, however, appears of less importance, seeing that the *minutiæ* of these details will be well known to those of our readers who are practically acquainted with ship-building, and described at length in published works dealing exclusively therewith. Moreover, by following the course just indicated, it seems possible to bring into fuller relief the salient features in the practice of a profession which constitutes one of our great national industries, upon our superiority in which we justly pride ourselves.

The history of ship-building is, in its earlier periods, involved in great obscurity, but it is nevertheless most interesting to trace the various stages of its development; and to those who desire to read for themselves the story of man's endeavour to make the structures he has fashioned capable of battling with the raging sea, we would strongly recommend Charnock's very excellent and laborious work,* wherein will be found drawings of all kinds of vessels, from the ancient galley up to the noble representatives of that class which, not long ago, were fondly termed "our wooden walls." For the present purpose the briefest sketch of this progress must suffice.

TYPE OF ROMAN GALLEY. FROM AN ANCIENT BAS-RELIEF.

In all probability the floating log formed man's first means of transport over the rivers and shallow waters which he desired to cross. By easy steps the construction of rafts, formed by fastening several logs together, would be reached; and the unwieldiness of these would probably suggest the use of "dug-outs"—*i.e.*, hollow logs; or it may have been that some accidental happening upon a log hollowed by natural causes suggested the imitation of the form by artificial means. It is well known that even at the present time such "dug-outs" continue in use among savage tribes, the ends of the log being sharpened, and canoes formed—a shaping which would soon be suggested by experience as the best for facilitating passage through the water. Some of the war canoes thus constructed are reported by travellers to be of large size, and capable of carrying a great number of men; but it is obvious that the limits of size in vessels thus made "out of one piece" would soon be reached, and then must have come the problem of constructing out of more pieces than one a structure of similar form, that should be water-tight, buoyant, and strong.

* "History of Marine Architecture."

Whether or not it was at this stage or an earlier one that the construction of "coracles"—*i.e.*, boats formed of hides stretched over wicker-work frames—began, we have no means of ascertaining; but whatever may have been the origin of the coracle it certainly is a device meriting admiration for its combination of lightness and strength. We are assured that, in vessels on this plan, the ancient Scandinavians undertook voyages to Iceland and other parts of Europe distant from their own shores; and one cannot but wonder at the daring which enabled these hardy adventurers to successfully navigate their apparently frail vessels across the stormy Northern Seas. Such frail barks could not continue long in use after the manufacture of tools, and the arts of working in wood became well known; but they are probably the earliest examples of vessels constructed of various pieces, and having a flexible waterproof outer covering, stiffened and kept to its form by an internal framing. It may be that in their construction we find the origin of a term even now in use among ship-builders—the "skin" of a ship, by which is meant that portion which prevents the water from passing into the interior of the vessel.*

Wood continued to be the material generally preferred for building floating structures, and the more civilised European nations appear to have considerably advanced in their knowledge of the art of working in it, even at the time that the Scandinavians were roaming far and wide in their coracles. By what stages these early wood ship-builders passed from the dug-out to the more or less finished galley cannot now be ascertained. Their progress must have been gradual and tentative; but from the very nature of the material in which they worked, and the form which they desired to give the vessels, they must have been led, before many attempts had been made, to adopt arrangements resembling in principle what we now term the "skin" or shell, and the frames or "ribs," stiffening the skin and preserving its form. The galleys so built were gradually increased in size and strength, repeated trials and enlarged experience leading to various changes and additions, the most notable of which was the construction of a complete deck or platform, upon which the warriors stood. By this means, what had been an open boat became changed into a covered vessel, and the ship-builder unconsciously adopted an arrangement which has since been recognised as one of the best that could possibly have been devised for securing structural strength as well as safety.

THE CORACLE, AS USED IN ANCIENT AND MODERN TIMES.

It may be interesting to give the dimensions of a Roman trireme, or galley with three banks of oars, as an example of what was regarded as a marvel of ship-building more than two thousand years ago. The length was about 110 feet, and the breadth 11 feet; that is to say, the galley was less than one-sixth as long as the *Great Eastern*, and little more than one-eighth as broad. In fact, it was originally intended to put on board the *Great Eastern* small steamboats, the size of which would probably have been greater than that of the Roman galley.

The principles of constructing wood ships having been established, were slowly developed as centuries passed on; and various types of ships were introduced, but with these changes we need not concern ourselves. Whatever the oddities of form may have been—and they were most singular in many cases—the same general principle underlaid all these constructions.* The outer skin was formed of comparatively narrow planks, fastened by bolts to strong internal frames or "ribs." The foundation of the structure was a keel, or longitudinal timber projecting from the bottom at the centre-line of the ship; and at the extremities there were continuations of the keel up to the top-height of the ship, that at the bow being termed the "stem," and that at the stern the "stern-post." There were also decks or platforms, the number and position of which varied with the size and type of the vessel. To use a well-worn illustration, the keel and its continuations might be compared to the breast-bone, while the frames crossing the keel at right angles resembled the ribs of a vertebrate animal, and the outer planking fastened to the frames corresponded to the flesh and skin. These are still the distinctive features in the structural arrangements of wood ships, as will be explained more fully hereafter. The details of these arrangements have, of course, been considerably modified and improved, and a far better knowledge of the theory of construction has been attained since the time that the earliest vessels having frames, planking, and decks were built; but for centuries no radical change was made in the *principle* of construction, and this fact is certainly noteworthy.

With the introduction of iron as a material for ship-building there was begun a period of progress such as had never before been dreamt of. Less than ninety years ago no iron vessel, of which any record remains, had been built, and for nearly twenty years the use of iron was confined to canal boats. Then came a change. An iron steamer was built, and made a successful voyage across the Channel; her success led to the construction of other iron sea-going ships; and although great opposition was made to their employment for a considerable time, the merits of the new material were so well established by trial that at the present time wood ships are falling into a secondary position in our mercantile marine, and the finest war-ships in the world are iron-built.

It scarcely seems credible now that at the outset there should have been a general belief that iron ships could never succeed, because they were built of a material which was, bulk for bulk, so much heavier than water; yet this was the case, and there are on record arguments to prove that "iron may be made to swim." Of course, such mistaken views were only entertained by those unfamiliar with the fundamental truth, that any body which displaces a weight of water equal to its own weight and that of its contents will float, no matter how heavy its component parts may be. Many persons who did not oppose iron ships on this ground, did so on the ground that the thin plating might easily be penetrated, and that then there would be a greater chance of their foundering than would occur in a wooden ship with her planking broken through. This objection was met, however, by the practical proof that by proper arrangements in the interior an iron ship might be made safer from danger of foundering than a wood ship—a fact which is now generally admitted.

These and many other objections to the use of iron were swept away, as was said, when experience became enlarged; and to this country undoubtedly belongs the honour, not only of initiating this great change, involving a departure from the practice of time immemorial, but of having kept the lead in the improvement of iron ships up to the present time. And we have reaped the greatest benefit from the change, as was but right. The United States, with their vast resources in timber fitted for ship-building purposes, were fairly beating us out of the field early in this century, competing as we did under such great disadvantages; but now, with abundant stores of coal and iron within our shores, and having such a wonderfully progressive iron manufacture, we are once more the ship-builders *par excellence* of the world.

Iron ship-building and steam navigation are indissolubly united in the history of the material progress of this country. The first iron ship which ventured to sea was a steamer; the great majority—we might almost say all—of the ocean steam-ships now at work are built of iron. Rapid and regular transit

* It may be interesting to state that small coracles are still in use amongst the fishermen on the Conway and other rivers in Wales.

* Those of our readers who have the opportunity, cannot do better than inspect for themselves the very extensive and interesting collection of naval models at the South Kensington Museum, if they wish to gain an idea of the changes alluded to.

across the sea is now looked upon as the most common occurrence; but these facilities for intercommunication have resulted from the fact that longer, finer, stronger, and more powerful steamers have been built of iron than could have been built of wood.

These general considerations must not, however, detain attention longer: we will briefly glance at the more practical subject of the structural arrangements of ordinary iron ships, and attempt to show in what they differ principally from wood ships. As was natural, the builders of the earlier iron ships copied as closely as was possible the details of construction which had proved successful in wood ships. In some cases they even went so far as to imitate in hollow iron the sectional forms of parts of wood ships which had been made of solid timber. These singularities soon fell out of use, however, and the system of building now generally adopted became common. The great features of this system may be summed up as follows:—A series of transverse frames or ribs, formed of angle-iron and plates, lying across the keel; an outer skin, formed of thin plates, strongly riveted to each other and to the frames; decks, or platforms, supported by iron beams, the ends of which are fastened to the ribs; and various strengthening pieces running throughout the length of the vessel. Hereafter, all these parts of the structure will be described and illustrated. For the present it must suffice to say that the superiority of a vessel so built over one built of wood is mainly due to the facts that iron plates and bars can be much more efficiently secured to each other, where they meet or join, than can timbers and planks; that the fastenings of an iron ship are formed of the same material as the parts they fasten, whereas there are metal fastenings in wood ships; that the facilities with which iron can be welded, bent, and shaped, render it far easier to dispose of that material in the way most conducive to strength than is possible in a wood ship; and that the union of all these qualities renders it possible to make a ship of given dimensions lighter and stronger if built of iron than she could be made if wood-built. This is a mere summary, but in future papers the points mentioned above will receive consideration, and in dealing with them an opportunity will be afforded of describing the improved methods of building iron ships which have been recently introduced.

The only serious drawback to the use of iron ships is one that was soon discovered, and has been the subject of consideration ever since, but has not yet been overcome: we refer to the "fouling" of the bottoms. The oxidation, or rusting, of the iron bottom-plating has been very fairly prevented by coating it with protective substances, but the growth of marine plants and animals has not, as yet, been prevented, although very many attempts have been made and numerous patents taken out. Some of the anti-fouling compositions answer much better than others, but even with the best the period during which an iron ship will keep a comparatively clean bottom is seldom more than twelve months, and in many cases less. This is, of course, a great source of expense, and when the bottom is foul the speed of the ship is decreased, sometimes to a very considerable extent on long voyages, or in tropical waters. The only remedy at present available is to place the vessel in a dock or other situation, where she is left high and dry, in order to clean and freshly coat the bottom. If any one should be so fortunate as to discover a remedy for this evil—and it is to be hoped that this may happen ere long—he will win a lasting fame, and remove the only weighty objection to iron ships.

A wood ship, as is well known, when the bottom is sheathed with copper or other metal, will keep free from fouling for a very considerable time;* and soon after iron ships began to be used another method of building was introduced, which was intended to combine the special advantages of iron and those of wood ships. This is known as the "composite system," and may be simply described as a combination of the frames, decks, and interior strengthenings of an iron ship, with the outer skin, or planking, of a wood ship. The former gives greater strength to the structure than would be given by corresponding parts made of timber; and the external planking enables copper or metal sheathing to be used in order to keep the bottom free from fouling. Many vessels have been thus constructed, and notably the famous China clippers engaged in the tea-trade, as well as other ships trading to distant ports. Experience has proved, however, that unless very great care is taken in building composite ships, galvanic action will be set up between the iron framing, etc., and the copper sheathing. On this account, probably, the system has not been generally adopted, its use being almost confined to vessels designed for long ocean voyages, or service in parts where there are no facilities for docking and cleaning.

Three classes of ships will, therefore, require to be considered in our further treatment of this subject, viz., wood, iron, and composite—this having been the order of their introduction into use. In each class, as we have seen, the three great heads under which the structural arrangements may be classified are—(1) the framing or internal stiffening of the skin; (2) the skin itself; and (3) the decks or platforms. This classification of the various parts of the hull being common to all the classes of ships, may be conveniently adopted; and under each head our endeavour will be to explain the special arrangements of wood, iron, and composite vessels, touching the methods commonly adopted in the construction of merchant ships, and those followed in ships of the Royal Navy, including the iron-clads. In all cases the treatment will be necessarily brief, but we trust not uninteresting.

* A few iron ships have been built for the Royal Navy having their bottoms sheathed with wood planking, outside which copper sheets are nailed, in order to prevent fouling. Attempts have also been made to introduce zinc sheathing on iron ships for the same purpose.

TECHNICAL DRAWING.—XLVII.

DRAWING FOR STONEMASONS.

STONE STAIRS.

Stone geometrical stairs have the outer end fixed in the wall, and one of the edges of every step supported by the edge of the step beneath it, and constructed with joggled joints, so that they cannot descend in the inclined direction of the plane, nor yet in a vertical direction; the sally of every joint forms an exterior obtuse angle in the lower part of the upper step called a "back rebate," and that on the upper part of the lower step, of course an interior one; and the joint formed of these sallies is called a "joggle," which may be level from the face of the risers to about one inch from the joint. Thus is the plane of the tread of each step continued one inch within the surface of each riser, and the lower part of the joint is a narrow surface perpendicular to the inclined direction or soffit of the stair at the end next to the newel.

The stone platforms of geometrical stairs—viz., the landings, half paces, and quarter paces—are constructed of one, two, or several stones, as they can be procured. When the platform consists of two or more stones, the first platform stone is laid on the last step which is set, and one end is "tailed in" and wedged into the wall. The next platform stone is joggled or rebated into the one set, and the end also fixed into the wall, and thus with every stone in succession until the platform is completed.

If there is occasion for another flight of steps, the last stone of the platform becomes the spring stone for the next step, and the joint is to be joggled as well as those of the succeeding steps, in the same manner as in the first flight.

Geometrical stairs executed in stone depend, says Mr. Nicholson, on the following principle—viz., that "every body must at least be supported on three points placed out of a straight line, and, consequently, if two edges of one body, in different directions, be secured to another, the two bodies will be immovable in respect to each other."

This last is the case in a geometrical stair; one end of a step is always tailed into the wall, and one edge either rests upon the ground itself or on the edge of the preceding step; the stones of a platform are generally of the same thickness as those forming the steps.

WINDING STAIRS.

The Helix.—The line of a staircase which winds round a well, or which is supported by a central newel, is called a *helix;* and as the information as to the construction of this curve has been given in "Projection," it will be our object now to show the application of such lessons.

It will be remembered that if a piece of paper of the form of a right-angled triangle be rolled round a cylinder, the hypo-

thenuse, or long side of the triangle, will generate a curve winding round the cylinder like a corkscrew. This curve is called the helix. Let us now see how far the instruction referred to applies in the delineation of a winding staircase.

If we stand on the ground and look up from the well of such a staircase, we shall see that the underneath portion of it forms not a line only, but a helical plane, contained between the lower end of the stairs towards the well, and the end where they are inserted into the wall. This would clearly be an extension in the plane of the helical line referred to in the last paragraph; but this is not all. If the edges of the stairs were united, another helical plane would be formed parallel to the last.

solid representing the height of the tread has been taken to be the same as the spaces into which the height of one revolution had been divided. Thus, the second curve, instead of beginning at A, starts from point 1′, and throughout the points are taken at one number higher than the previous one; thus the perpendicular from 1 in the plan intersects the horizontal drawn from 2′, and so on. The inner pair of helixes surrounding the well are projected in precisely a similar manner from the circle K M O.

In this lesson is given a portion of the plan of a well staircase, and it is hoped that, after the instruction conveyed by the preceding lessons, the student will be able to draw the whole plan, and project the staircase from it.

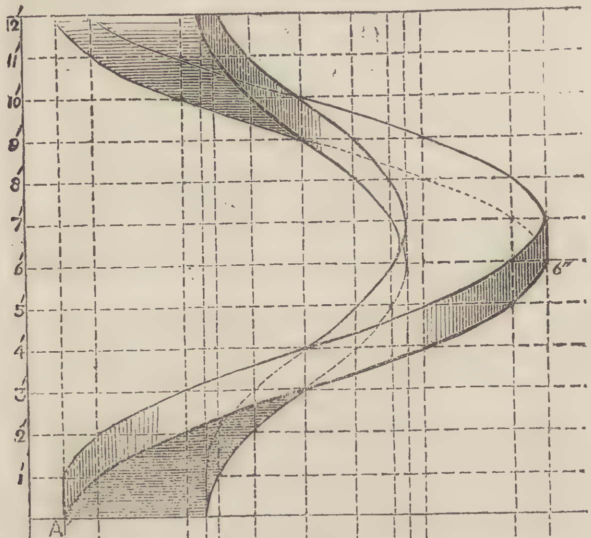


Fig. 427.

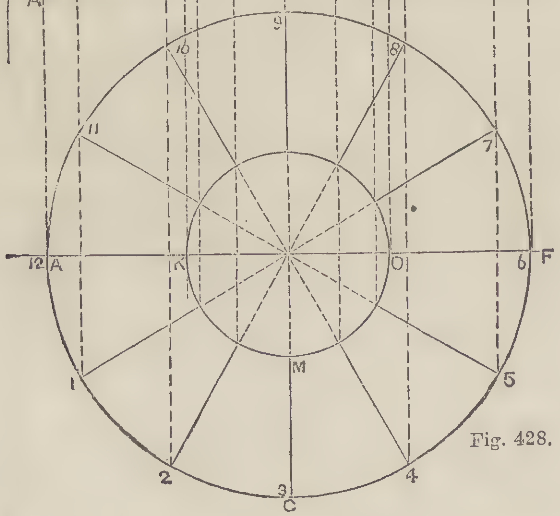


Fig. 428.

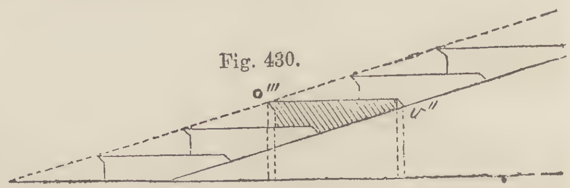


Fig. 430.

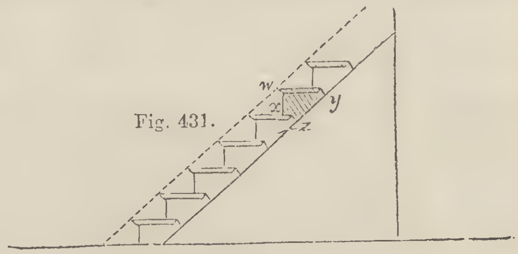


Fig. 431.

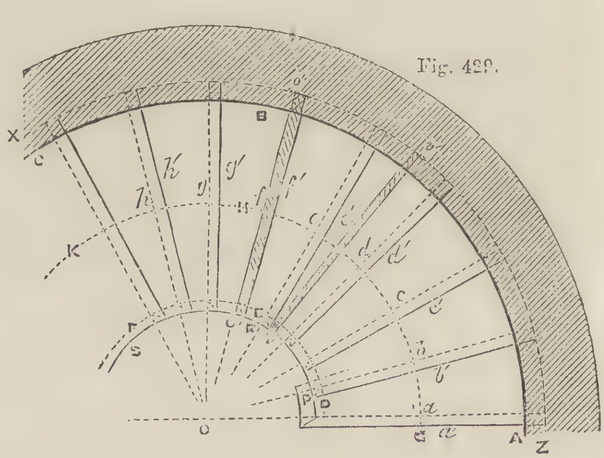


Fig. 429.

A winding staircase, then, is formed by a solid contained between two helical surfaces and two concentric cylinders—viz., the wall and that in which the smaller ends of the stairs are situated. Such a solid is shown in Fig. 427.

Let A C F (Fig. 428) be the plan of the well, and K M O the plan of the cylindrical space between the inner ends of the steps; the width M C representing that of the solid in which the steps are contained, their common axis being vertical.

The plan having been divided into twelve equal parts (not *necessarily twelve*), divide the height of one complete revolution into a corresponding number—1′, 2′, 3′, etc. Perpendiculars drawn from 1, 2, 3 in the plan, intersecting horizontals drawn from 1′, 2′, 3′, will give the lower curve A′ 6″ 12′, which it will be seen is hidden by the thickness of the solid when it has passed 6″, but emerges again at 9′.

For convenience in the present drawing, the thickness of the

Draw the circle A B C (Fig. 429) (the inner wall of the well), D E F (the circumference of the cylinder on which the inner ends of the steps will be situated), and an additional circle (G H K) in the middle of the length of the steps, on which set off the points *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, the real width of the steps at their middle), this width being measured from *rise* to *rise*.

Through these points draw lines (shown in dots in the illustration) to the centre O.

Parallel to these lines, draw the lines *a*′, *b*′, *c*′, *d*′, *e*′, *f*′, *g*′, *h*′, at a distance equal to the width which a moulding would project beyond the rise of the steps, and draw also the circle P R S, in which will be situated the visible ends of the stairs.

It is now advisable to leave the plan for a time in order to draw the true form of the ends of the steps shown in Fig. 430. When these have been completed the widths are to be set off on the circle X Z, as shown from *o*′ to *v*′, the figure *o*″ *o*′ *v*′ *v* being

the plan of the complete block. If these widths are given in the plan, the sectional elevation may be projected by setting them off on a horizontal line, the heights being marked on a perpendicular; the intersection of these will then give the required forms, as shown in Fig. 430, $o'''v''$ being the form of the templet.

Fig. 431 is the development of the inner ends of the steps, and *w x*, *z y* is the templet, which is to be obtained in precisely the same manner.

The revival of Gothic architecture in this country has within the last few years progressed so rapidly that a knowledge of its principles has become important to the stonemason, and the whole subject of "Gothic stonework" will therefore now be treated of in a separate course of these lessons.

GREAT MANUFACTURES OF LITTLE THINGS.—II.

BY CHARLES HIBBS.

BUTTONS.

BUTTONS are very small matters, and it might appear that they were very simple also, but the fact is that there is scarcely anything else which has so taxed the ingenuity of man to produce. They have been made of every conceivable substance which could be teased into the semblance of a button by any means known to mechanics. The three kingdoms (those of Nature, not of Great Britain) have been ransacked for materials. From the animal kingdom have been obtained ivory, bone, horn, hoof, pearl-shell, leather, cloth, and silk. The vegetable kingdom has given wood, caoutchouc, linen and cotton fabrics, papier-mâché, and that beautiful substance known as vegetable ivory. The mineral kingdom has yielded, besides the metals (of which all those known to commerce are used in button-making), glass, porcelain, and a certain mineral earth, of which some buttons have been lately made. These three classes of substances would seem to suggest a convenient division of our subject, but the button trade, insatiate for new patterns, combines very frequently two or more substances in one button, so as to gain exhaustless variety by their transposition. A better classification for our purpose will be one based upon the different methods of manufacture. Thus, one class or family of buttons is produced by stamp and press work, processes somewhat akin to those described in our article on steel pens; this will include all metal and covered buttons. Another class consists of those which are turned by cutting-tools in a lathe, such as mother-of-pearl, ivory, etc. The third class will comprise those which are moulded into form by pressure, as horn, porcelain, etc. It will be seen at once that these three sets of processes differ so widely as to constitute almost three distinct trades; indeed, within the button trade there are distinctions far greater than often exist between one trade and another, and there is no one single manufacturer who makes all kinds of buttons.

The metal button trade has the first claim on our attention, as it is certainly the most ancient, and perhaps even yet the most important, on account of the great number used for all kinds of uniforms. The buttons that our forefathers wore (for ornament, not for use) were principally of metal. Jos. Strutt says: "In the paintings of the fourteenth and succeeding centuries, these ornaments frequently appear on the garments of both sexes, but in a variety of instances they are drawn without the button-holes, and placed in such situations as preclude the idea of their usefulness. Generally speaking, they were made of gold or silver, or are so depicted, with very few exceptions." The old English gentleman tied up his doublet and trunk hose with innumerable points, or little strings; a somewhat tedious process, but then the people of those days had plenty of time on their hands. In the metal button of our day, this old idea of ornament seems to linger yet, and from the uniform of a lord-lieutenant (said to be the most gorgeous left to us in these degenerate days) to the liveries of servants of persons of wealth and rank, the buttons are not only showy in themselves, but are sewn on "in such situations as preclude the idea of their usefulness."

The substantial metal badge of olden times has its nearest antitype in the modern livery button. These are known in the trade as solid metal buttons, being formed, with the exception of the shank, of one piece throughout. The first process is to cut out of sheet metal (brass, with a more or less proportion of copper, according as it is required for gilding or silvering) the discs or blanks. It is performed in precisely the same way as the process, formerly described, of cutting out steel pens, with this exception, that the metal, being much stouter, requires a more powerful press. Some large firms use a self-feeding, self-acting machine for this purpose, which cuts out a whole row of blanks, all across the strip of metal, at one blow, and delivers its blows with the rapidity of lightning, cutting out as many as 2,000 gross in a day; but these machines are only found to be economical where very large quantities of one pattern are required at one time, on account of the time taken in setting the tools. The discs are then annealed, and a little indentation is made on one side by means of a press, just to receive the end of the shank. They are then "domed up," *i.e.*, beaten into a convex form, by a single blow from a stamp on the under side. The shanking follows, an operation requiring no inconsiderable amount of skill. It is performed by women, as are all the delicate processes in the button trade. The operator dips the end of the shank into a pan of wet solder, sticks it in the recess, and fixes it there with a little iron cramp, all in the duration of a wink; and the little trays on which she places them neatly in rows for the furnace get full with marvellous rapidity. Exposed to heat until the solder runs, they are then allowed to cool, and on the cramps being knocked off not one shank in a thousand will be found to be in the slightest degree out of the upright, while the adhesion is so perfect as to make the button practically all one piece. They have then to be cleaned by a method peculiar to copper and brass articles, viz., that of "dipping," which must be described with some minuteness. The liquid in which they are dipped is a more or less strong solution of aquafortis, mingled with some other ingredients, such as crude tartar, etc., according to the different receipts in use at various factories. The articles are at first immersed for some time in a weak bath of this acid, or "pickle," as it is termed, which takes off the "scale" left by the annealing, and effectually removes all impurities. After this they are dipped quickly, by means of a perforated earthenware vessel holding a small quantity at a time, into a very strong solution, several times, one vessel after another, the dipper well shaking them up each time, and finally rinsing them thoroughly with cold water. This treatment renders them perfectly bright and clean. The acid is a very destructive fluid to deal with, and the workpeople have to be protected with thick pinafores and aprons of green baize, to save their clothes from being burnt in holes. It has to be performed in the open air, or at least in an extremely well ventilated shed, to allow for the escape of the noxious fumes of the acid; and when the atmosphere is lowering, thick yellow clouds of stifling vapour hang about, very distressing to the respiratory organs. It is disputed whether the occupation is actually hurtful to life; there are instances of dippers having reached a respectable old age, but no person whose lungs were in the slightest degree affected could practise it.

The buttons have now to be plated. The best buttons, as the old hands in the trade fondly say, were those plated by the old mercurial process, which ensured a tolerable thickness of the precious metal being laid on; but that is now entirely superseded by the more delicate, if more deceptive, method of electro deposition. Even now, the plating must not be too niggardly, or it would not stand certain rough usage yet to be described, but unscrupulous makers would be sure to find out the extremest limit of tenuity to which it would be safe to go. It is said that the prosperity of this trade has run in cycles. At intervals of half a century or so, the makers, acting upon a strong instinct of self-preservation, have agreed with each other to put gold enough on their buttons to last for a decent length of time; but after a short interval of spasmodic honesty, the greed of some would prompt them to stint the allowance, and from thence would come underselling and universal depreciation, ending by loss of trade from customers' disgust at finding that the articles began to look brassy after the slightest wear.

After the plating, the next step is the burnishing. This is a very beautiful and curious process to look at, the change produced in the appearance of the button being perfectly magical. The burnisher works with an ordinary foot-lathe, the driving-wheel being perhaps six feet in circumference, while the pulley, which it drives by means of a gut, is less than one inch; thus generating an enormous speed. The button is stuck lightly on

the end of a "chuck," or peg of box-wood, revolving in the lathe; the workman presses a tool against it, beginning at the centre, and gradually directing it to the side, and in an instant the metal surface seems to mantle over with a smile of the most effulgent brightness. The burnishing tool is a piece of a peculiar stone found in Derbyshire, set in a handle of wood; it is of a greenish colour, and is the best substance yet discovered for imparting a perfectly smooth surface. Its qualities are very variable, and can only be ascertained by trial; consequently, although the original cost of the stone may be trifling, a piece no bigger than a nut, which has been proved to be good, may be worth three or four pounds.

Up to this point the button has no pattern or device upon it whatever, being only a plain disc of metal, very rich in colour and brightness. It would seem that to touch it would be to tarnish it, but it has yet to receive under a stamp a single heavy blow that shall give it form and feature. The dies which are to give the impress are beautiful specimens of workmanship. The upper die—that which is fixed in the stamp-head, and which is to descend with crushing force upon the innocent button—is cut into the inverted semblance of the face it is to wear for the future—the crest, the motto, if any, and the ornamental rim. Its own face is polished to the utmost point of brilliancy, and it is known as a "bright" die. The lower die, which is placed with the utmost nicety in the stamp-bed, immediately under the descending force, is cut correspondingly, to give the impress to the under side of the button, usually consisting merely of a circular inscription containing the maker's, or more frequently the tailor's, name and address. This die is split, or made in two halves, opening right across the centre of the button. At the upper edge of both walls of the parted die a small recess, the exact shape of the shank, is cut, so that when the two halves are put together, with the shank between them, they hold the button tightly in its place. The stamper puts his foot into the stirrup of the rope, jerks the stamp-head up and down a time or two to give it "swing," and having got it high enough for his purpose, lets it fall with its dead weight on the bright and vacant disc. It is thenceforth meaningless no longer. On the stamp being lifted, the device will be found to be raised from the surface of the button in clean and bold relief, its brightness still unsullied in every part, and the plating, if it has not been *too* finely attenuated, uninjured in the slightest degree. The under side will have also received an equally clear impression of the letters, together with (an unavoidable defect) that of the line of junction of the two half-dies, which makes a very fine seam across it. Of course it need not be observed that the greatest care has to be exercised in the making and preservation of these dies, since the slightest flaw in the steel itself, the slightest rust upon the polished face, the slightest suspicion of a speck of dirt, would be irretrievably printed on the now valuable button. The marvel to the uninitiated, who are not aware of the extreme ductility of the metal under manipulation, is that it should be capable of being forced so readily to re-distribute its parts, becoming thinner in some parts and thicker in others, with all the facility of sealing-wax, not giving the slightest sign of fracture from the violence which has been offered to it. The degree to which it will bear this depends largely on the original quality of the metal, no less than upon the care with which it has been annealed.

The button is now finished, with the exception of having its edges dressed carefully in a lathe. The processes here described are for the production of a *bright* button; but if the surface is to be "dead," or frosted, the order of some of them will be reversed. The buttons will be stamped in the rough, immediately after leaving the pickling troughs; they will then be gilt; and the burnishing, which will be the last process, will only touch the prominences of the impression, which will be cut with a special view to being so relieved.

If we have carefully followed the various operations in the production of a livery button, it will enable us to understand much that comes after in the manipulation of other descriptions of metal buttons. Those which adorn the garments of our public guardians, civil and military, and which look so solid and massive, are in reality only shells. They are cut out of thinner metal than the solid buttons, and the two discs, which, when brought together with their concaves face to face, have to be joined to form one button, are treated separately. The upper disc is cut larger than the size of the button when finished, to allow of its edges being turned down so as to overlap and clip the under one, which is cut out somewhat less. Both halves are domed, as before described, but the upper half has its edges bent down sharply, and prolonged by the same pinch of the press, so as to form a very short cylinder with a rounded top. Each half receives its particular impress with a press or stamp, and the lower half is fitted with a shank, which for military purposes is thus made:—Two holes are punched in the centre of the disc; the shank, which is simply a piece of wire bent in the form of a staple, is inserted by its two ends, and fits loosely in the holes; a girl seizes the shank with a pair of stout, blunt-nosed pliers, between whose jaws an incision is made corresponding to the length of shank that is intended to remain outside the button; she then holds the whole under a press, and a broad, wedge-shaped punch coming down, turns over the two ends, and clenches the shank inside the hollow disc. When the button is finished, the shank can be pushed right into its body, until the bend lies snugly in a little hollow formed to receive it; the advantage of such an arrangement being, that in packing uniforms (which is done sometimes by hydraulic pressure) for distant stations, the shanks do not cut the cloth. An inflexible shank is made of the more graceful circular shape, and is riveted inside the bottom disc.

When the two halves are finished and brought together, a single pinch of a press is sufficient to turn the edges of the upper half neatly over, and make it hold the inferior portion with an embrace that cannot be relaxed. The accommodating metal contracts itself under pressure without the slightest difficulty, and the two parts of the button are thereafter one. The final processes depend upon the quality of the article. Some are simply lacquered, being only for the rank and file; others will be magnificently gilt and burnished.

To give some idea of the extensive plant required to carry on this branch of the button trade, it will be sufficient to state that for the army and militia alone more than 3,000 pairs of dies would be required. If to these we add what would be necessary for the volunteers, the navy, the coast-guard, the police, the convict prisoners, etc. etc., we shall be able to conceive that a manufacturer who is in the habit of contracting largely for such orders must have a perfect museum of dies, representing many thousands of pounds.

The inferior branches of the metal button trade comprise chiefly trouser buttons. Some of them are shell buttons, with various fanciful differences of construction, but the staple is perhaps the old-fashioned four-hole button, made in one piece. They are made of copper, brass, iron, zinc, or tin, and of many qualities. The cutting-out machine before described can be so modified as to cut out the blanks and pierce the four holes at one operation; after which there is little more to do. The holes are rymered—*i.e.*, the edges rounded down, so as not to cut the thread—by a little girl at a press, who squeezes one hole at a time between two conical punches, counter-sinking them by pressure. A single blow from a stamp brings the plain piece of metal up to a finished button, tailor's name and all.

We have now to speak of the most important revolution the trade has ever yet known, and which has led to the most perfect of its many ingenious devices. This was the introduction of the covered button, one of the earliest patents for which was taken out in 1825. Probably long before that time our grandfathers had conceived the idea of covering the metal button with cloth, to save the trouble of eternally furbishing it up with the elaborate set of apparatus which was then a necessary adjunct to every toilet; but as the covering would be done with a needle and thread, it would be but a clumsy makeshift compared to the neat and well-shaped Florentine button, with flexible shank, which, as soon as it appeared in the market, rapidly rose into favour, and carried all before it. The first covered buttons were made with the customary wire shank, but this speedily gave place to the little protruding tuft of canvas which would take the needle in all directions, and lie down close to the cloth. As we are not writing a history of the trade, it would be superfluous to dwell on the many modifications and improvements which this favourite button has undergone; our task, which is a far harder one, is to endeavour to describe, in intelligible language, the ingenious and complicated processes of its manufacture.

By way of approaching the difficulty by easy degrees, let us take first for illustration the well-known simple linen button

used for under-clothing, etc. If the reader will examine one, he will see that it consists of two pieces of linen stretched on a ring, the edges tucked in and fastened in a way he cannot discover. Our grandmothers' substitute for this was a ring with threads worked over it, and gathered in the centre. The new button is much neater, much more durable, and in every way an improvement, but the original idea of the ring has been retained. Now let us see, in the first place, how this ring is made. It is not made of wire; if it were, there could be no such hermetical fastening of the linen covering, as we shall see. It is a tube; and it is made precisely in the same way as rings are made—viz., first, a disc of thin metal is cut out, a little larger than the intended button; then a circular piece is cut out of the middle of it, leaving it of an annular form; then it is put under a press, and a pair of tools double up the rim into the shape of a gutter all round; another pair of tools bring the two edges of the gutter nearer together, bending them down gracefully, and preserving the tubular curve; a third pair completes this juncture, and forms a ring of perfectly round tube, with a seam that cannot be detected by the naked eye. Now it is evident that if we can get our piece of cloth stretched over the back of this ring, bringing over the edges and neatly tucking them into the joint just before its final pinching up, and if we can manage to enclose them in the death-grip of the metal at its last process, we shall have a covered button that no fair play can undo. This is exactly what is done, but, in addition, a smaller piece of cloth is stretched over the face, and fastened into the same joint, thus completely clothing the button, and concealing its anatomy.

How the different parts are brought together, placed in position, and held there while the all-important juncture is effected which makes the whole thereafter indissolubly a button, can scarcely be seen by a spectator watching the process, much less understood from a written description. You look down the vista of a long work-room, and see a row of little girls sitting together at a work-table as closely as if they were at school, each pair of little hands nimbly placing the rings and bits of cloth into little steel traps, and handing them across the table to a senior girl seated opposite, who first performs some feat of legerdemain which sets the interior mechanism of the trap to work, presumably in pushing everything into its place, and then holds trap and contents together for an instant under a press, gives a little pull, and the thing is done. Each pair of workers is making buttons as fast as you can count; the empty and the charged traps are passed across the table with noiseless activity; and a series of heaps of beautifully-finished buttons, without a wrinkle in a million of them, are accumulating silently in the little drawers under the bench, through holes in which they fall as they are made. All is beautifully clean, and the faces of the children are rosy and healthy, and they look happy withal. "Half-timers every one of them," said the courteous gentleman who was doing the honours of the establishment to the writer of this paper, "their duplicates are at school. By-and-by you will see some of them come in with their satchels, for many prefer to bring their dinners here, rather than eat them at home." "Have you found much inconvenience from the working of the Factory Act?" we asked. "None whatever," was the reply. "At first we had some little difficulty, and, as we pay the children's schooling ourselves, it has involved a trifling expense, but we get a better class of girls through it. Each one of these children will pass to the other side of the table as she gets old enough, and we find that those who have gone through the regular course of schooling (which we insist on, as far as we are able) are much better hands than those we used to take indiscriminately." In other parts of the establishment the fine linen cloth is being cut up into discs with the press, in the same manner as the metal blanks are made.

One large firm in Birmingham cut up in one year no less than 63,000 yards of linen cloth and 34 tons of metal for this article alone. The linen is of the finest quality, and has to be specially manufactured for the purpose.

The reader will now, it is hoped, be able to understand the theory of the making of all kinds of covered buttons. Their name is legion, and many ingenious variations of detail occur in their manufacture, but the principle is in all cases the same, advantage being taken of the ductility of the metal to make it clasp the woven material in a tight embrace. The covering of the common Florentine button is not stretched over a ring, but over a plate, with its edges turned over; a second smaller plate, with a hole in its centre, is placed against it, enclosing between them a canvas disc, of which a bulge, with a little padding in it, has been pushed through the hole. A squeeze of the all-powerful press brings the clothed edges of the superior plate over all, and effects a junction which can never be torn asunder.

We must leave for a subsequent paper descriptions of the interesting processes employed in the production of some widely differing members of the large button family.

WEAPONS OF WAR.—XIII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

ARTILLERY CARRIAGES.

CARRIAGES FOR GARRISON ARTILLERY.

THIS class of ordnance, as its name implies, is intended for the armament of permanent forts and batteries, which, being usually constructed long before the approach of an enemy, are furnished at the will of the occupier with guns of the heaviest and most destructive nature.

Prior to the introduction of armour-plating in ships and forts, the heaviest garrison-gun was the 68-pounder, of 112 cwt. Now we have rifled guns of seven, nine, twelve, and twenty-five tons commonly supplied for this service; and so far as the working of the gun is concerned, there is no reason for limiting its weight to 50 or even 100 tons. It will be at once obvious that the fixed positions to be occupied by these guns, and their increased weight, impose great modifications in the make of their carriages, as compared with those for the field artillery. Thus the third condition stipulated with respect to these latter (*vide* Article X.) is that the carriage shall be adapted for rapid movement, a condition quite inapplicable to garrison service. So, also, portions of the first and fourth conditions, relating to travelling and to the conveyance of the gun-detachments. The sixth, too, as to convenient stowage on board ship, becomes a point of third-rate importance, it being presumed that the arming of our fortresses across the sea admits of being carried on gradually, and not during a war pressure. On the other hand, the extreme accuracy of artillery fire from rifled guns imposes a fresh condition on the carriages for our garrison artillery, which, being stationary, naturally present a tempting object for an enemy's fire if greatly exposed to view.

The chief conditions to be fulfilled in a garrison-gun carriage may be thus stated:—

1. That it shall furnish a convenient and secure support to the gun, both when in and out of action.
2. That it shall be of a form easily under control, and adapted for giving accurate direction to the gun when in action.
3. That its construction shall be such as to admit of the least possible exposure to the enemy either of gun, carriage, or men working them.

Taking the first of these conditions, the trunnions, which are common to all guns, field, garrison, and naval, allow of the same general arrangements for garrison carriages as for those of the field artillery. Semi-circular trunnion-holes sustain the gun, which can revolve freely in a vertical plane for purposes of elevation and depression. They sustain the greater part of the shock when the gun is fired; consequently the "cheeks" or "brackets," into the upper surfaces of which they are cut, must be very strong. In the old smooth-bore carriages (Figs. 1, 2) these brackets, A A, are of oak. They are rigidly held apart at a distance suitable to receive the gun between them, and are connected by a stout oaken block, B, called a "transom," which is inserted, or "housed," into the inside surface of each bracket, and is bolted securely to them. The brackets are further secured in a similar manner by front and rear axletrees, or by a front axle-tree, C, and a rear "block," D, all of which are made of oak.

All natures of smooth-bore guns have considerable preponderance, their centre of gravity being well behind their trunnions; hence a third point of support must be found for the gun towards its breech. This is supplied in the simplest constructions by a "quoin," E, which is a wedge-shaped piece of wood placed immediately under the breech, and resting on a block, F, called a "stool-bed," the front part of which is hinged to a horizontal bolt, the hind part being supported by the head of an elevating-screw, G, which is held and works up and down in the rear block. Thus the gun is securely sup-

ported in its carriage. This latter is supported on the ground either by four low iron trucks working on the axletree arms, or by two front trucks, M, and a rear block, D. This block rests on the stone platform prepared for the carriage. The centre of gravity of gun and carriage is well within the four points of support thus furnished, so its stability, when not in action, is assured. When in action, however, the same law which necessitates a certain length of trail in the field-gun carriage is equally operative in all ordinary garrison carriages. The angle which a straight line drawn from the axis of the trunnions perpendicularly to it, in the direction of the rear line of support, makes with the ground-plane or platform must be kept within certain limits, to prevent the carriage from turning over backwards when the gun is fired. This angle need not be so small with garrison as with field carriages, the platforms on which they recoil being comparatively even and regular.

Passing on to the second condition, the simple form of carriage we are now considering will be found defective in facilities for laying the gun correctly under certain circumstances. The carriage, as has been already stated, stands on a stone platform. This platform is not laid level, but is given a slope towards the front, or parapet, of about 2½ or 3 degrees, a construction which much assists the working of the gun, and prevents excessive recoil on firing—in fact, so controls the carriage as just to bring the muzzle of the gun sufficiently behind the parapet to admit of loading at the muzzle with ease. After the gun is loaded, it must be run forward so as to bring the muzzle into the embrasure, and well in front of the interior slope of the parapet, before it is fired, otherwise the force of the explosion would act destructively upon the work. In this operation the slope of the platform renders valuable aid. By means of a roller-handspike, H (Fig. 3), which is placed under a socket, K, the rear block of the carriage is lifted just off the ground. The carriage may then be said to be on three wheels, namely, the two front trucks, and the roller of the handspike. Then, favoured by the slope of the platform, a very slight impulse suffices to move it forward into the firing position. A lateral motion, which can also be given to the hind part of the carriage in turning the roller-handspike either to the right or left, will, with the assistance of common handspikes, give the necessary horizontal direction to the gun, or this object can be attained solely by the leverage of common handspikes applied under the rear of the brackets. The vertical direction is given by means of the elevating-screw, G, worked by the lever-arm, L.

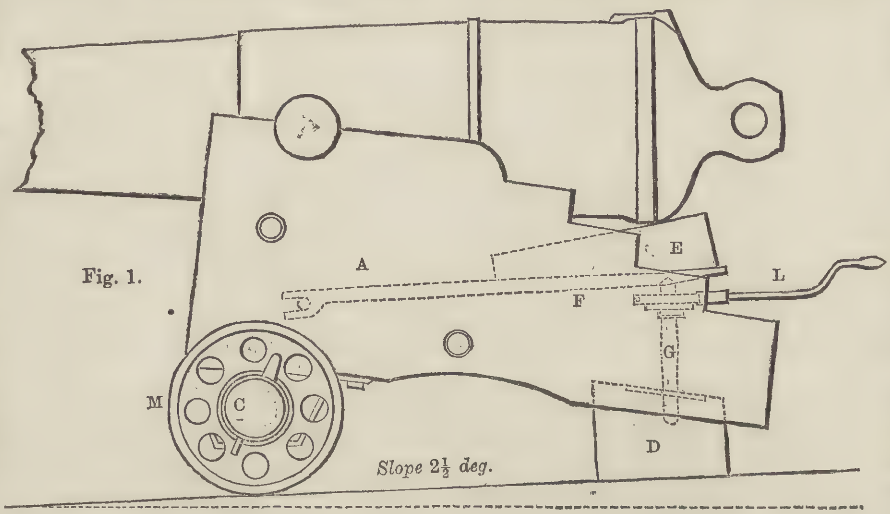


Fig. 1.

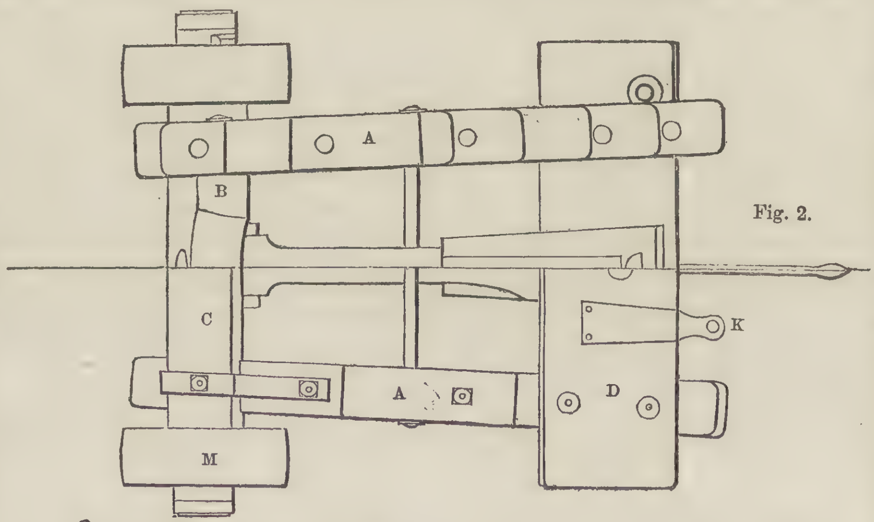


Fig. 2.

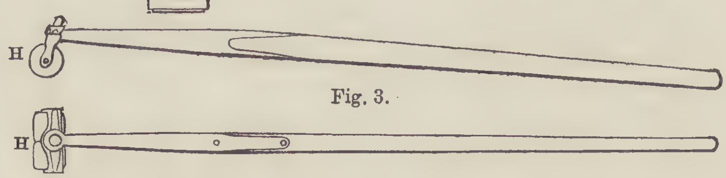


Fig. 3.

This form of carriage, while commending itself on account both of simplicity and in working, is only suitable for guns not exceeding 3 or 3½ tons in weight (heavier would prove unwieldy), and occupying positions where the lateral direction of fire at long ranges is circumscribed. The necessity for thus limiting the lateral direction is owing to the deviation of the line of sight from the line of fire when the distance of the object renders some elevation above the line of sight necessary to prevent the shot falling short. This so-called elevation is always given in a plane at right angles to the axis of the trunnions by means of a tangent scale attached to the breech of the gun, and working in that plane. If then, when firing at elevations above the direction of the object, the axis of the trunnions happens to be out of the horizontal, the divergence of the line of fire from the line of sight will no longer be vertical, and some horizontal error ensues. This error increases with the elevation of the gun, the inclination of the trunnion axis, and the length of the range. The exact amount of lateral deviation, in linear measurement, from the object aimed at, is obtained by means of trigonometrical expression, in which the known quantities are the length of the range, the inclination of axis of trunnions, and the nominal elevation of the gun. It has been said that carriages of the class under consideration stand on ground platforms which slope at an angle of 2½°, or

thereabouts, towards the front of the work. If, then, the gun is fired in a direction either to the right or left of this front, one of its trunnions will be thrown above the other, and if firing at long ranges and high elevations, the error admitted becomes important. For example, let us suppose a nominal elevation of 7° given to a 32-pounder smooth-bore gun directed at some object 2,500 yards away, the line of sight making an angle of 30° with a line perpendicular to the front of the embrasure, the slope of the ground platform being $2\frac{1}{2}$°; then the real error admitted will be found to amount to about forty feet, that being the distance which the shot would fall either to the right or the left of the object. So serious an error cannot be disregarded; consequently, where breadth and length of range combined are required, some more perfect arrangement must be resorted to. In providing flank defence for ditches and faces of works within short range, this carriage is very suitable; also over a high parapet, no better position of pivot could be chosen than the centre of the platform. These platforms for the lighter classes of guns are strongly built of timber; but for guns of seven tons and upwards, all platforms are of wrought iron (see Figs. 4, 5). Every platform stands on four low iron wheels, or "trucks," A A, so formed and attached to it as to roll on horizontal iron bars curved in the form of arcs of circles, the pivot forming their proper centre. These bars or "racers," as well as the pivot, are firmly bedded in masonry. As the gun-platform revolves upon these horizontal racers, the trunnions are kept also horizontal, whatever the direction given to the gun. Thus the error pointed out as occurring in certain cases with the sloping ground-platform and common standing-carriage, is at once removed. It has just been said that sometimes the pivot is in the embrasure, and beneath the front part of the gun when in the firing position, as in Fig. 2. Then, however,

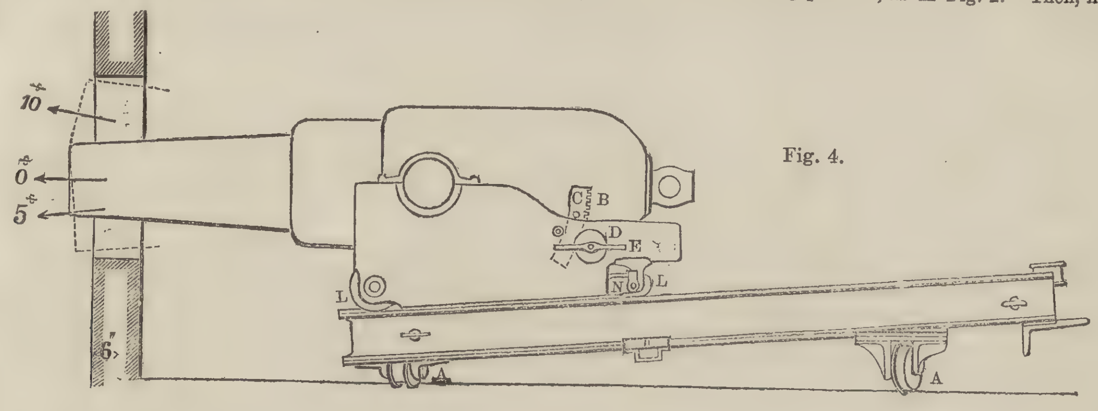


Fig. 4.

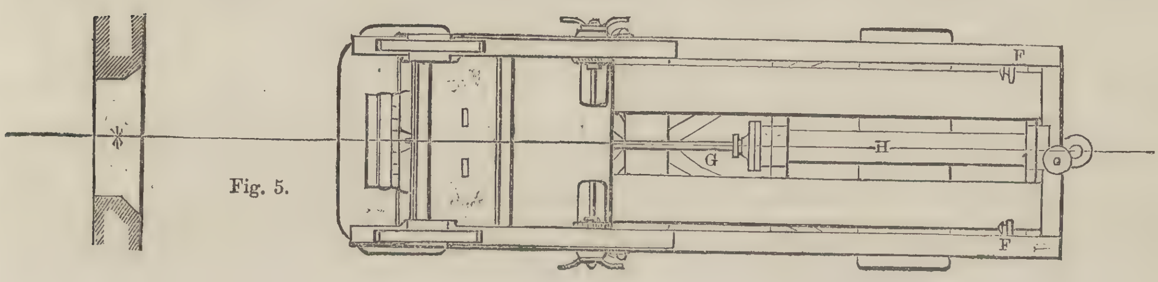


Fig. 5.

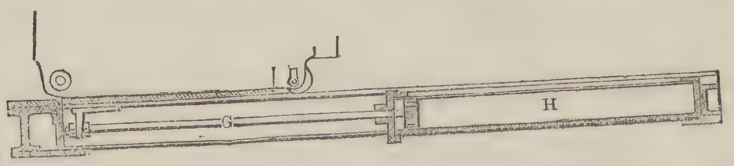


Fig. 6.

for long ranges, where the line of fire is confined almost to the direct front. It is not intended to carry the heavier natures of garrison-guns; in fact, the 64-pounder rifled gun and the 32-pounder and 8-inch smooth-bores are as large as can be efficiently worked on these carriages. For guns of heavier metal, greater facilities in the processes of running up and of altering direction must be obtained, and a special mechanism is designed for communicating horizontal angular motion. The sloping platform on which the carriage recoils is itself made to revolve on a horizontal plane, round a pivot situated either in or behind the parapet. This pivot may be either in front, behind, or in the very centre of the platform, according to the width of range required of the gun and architectural considerations. For instance, if the gun is to occupy a casemate, and to fire from an embrasure, that position of pivot which will give the greatest horizontal range will be in the embrasure, and under the front part of the gun, when the latter is run out to the firing position. If, on the other hand, the gun is intended to cover a wide extent of ground, firing it is *imaginary*, not real, which it would be if situated anywhere else.

A real pivot would be inadmissible in this exceptional position; as no rigid connection between it and the platform could be secured without greatly weakening the face of the work. It is, of course, advantageous to use real pivots when practicable. In using the imaginary, or "A" pivot, as it is called, the trucks are kept on the racers solely by flanges similar to those with which the wheels of railway carriages are made. When material pivots are used, they are an important auxiliary to the flanges in securing the platform on its racers. The plane of revolution being horizontal, the platform is favourably placed for movement with the object of giving lateral direction to the gun. By the aid of tackle hooked to the platform at one end, and at the other to an iron loop suitably placed in the masonry, sufficient power is obtained for traversing the heaviest guns; but with them the operation is slow, and it has been deemed expedient to correct this want of speed by substituting a toothed-wheel system of "traversing gear," attached to the platforms, in place

of the original tackle. The principle upon which it communicates motion to the platform is by causing the trucks to revolve, the power being applied at one or two winch-handles working in the rear of the platform, and being increased to the extent which experience has proved to be most efficient, by a system of pinions and wheels interposed between the winch-handles and the trucks. The horizontal direction is thus given to the gun rapidly, and without the admission of any error such as we have seen to obtain, under certain conditions, with a common standing-carriage working on a ground-platform. With respect to vertical direction, the necessary motion is imparted to the heaviest natures of guns by simple mechanism which, as with the lighter descriptions of ordnance, is attached to the carriage. A toothed arc of iron, B (Fig. 4), is connected with the gun on each side by a pin, C, about which the arc is free to revolve. These arcs are geared into pinions attached one to each bracket of the carriage. The pinion is rigidly connected with a short shaft or spindle, which passes through the bracket from its inner to its outer surface. Here it is fastened to an iron disc called a capstan-head, D, round the periphery of which a number of holes are drilled, for the purpose of receiving one end of an iron-pointed lever, at the other end of which the power is applied, causing the capstan-head, and consequently the pinion, to revolve, thus moving the arc up or down, and with it the breech of the gun, which, revolving about its trunnions, attains the required elevation or depression, and is held in position by means of a screw jamming-lever, E, which clamps the capstan-head against the bracket. The motion thus given is sufficiently powerful and rapid, but is scarcely so delicate as might be desired for the highest accuracy in laying. The clamping arrangement, too, has at times been found ineffective. On this account the following modification has been tried, and has been found to remove both defects. A worm wheel is substituted for the capstan-head; into this an iron worm, attached to the outside of the bracket, is geared. The shaft on which the worm is fixed is furnished with a hand-wheel so placed as just to clear the top of the rear portion of the bracket. No special clamping arrangement is needed.

It is necessary to control the recoil of the gun and its carriage, so that they shall be stopped before reaching the end of the platform; for if the carriage came violently in contact with the stops, F F, fixed at the extremity of each side of the platform, the various parts of the structure would soon become greatly strained, rendering the gun liable to temporary disablement. Various expedients have been resorted to for absorbing the recoil, some by means of friction, applied either before or immediately after its commencement, and continued with a constant resistance until the carriage is brought to rest: the compressor, which causes the friction by means of screw power, being attached to the carriage; and the baulks of wood or bars of iron on which the compression is applied being laid longitudinally from front to rear of the platform, with which they are strongly connected at both ends.

Another application of friction has been designed, with the object of gradually increasing the resistance from nothing at the instant of firing until the motion of the carriage is arrested. This is attained by interposing between the compressor and the bars compressed some elastic medium, such as india-rubber or steel springs, and making the bars wedge-shaped in horizontal section, the wider end being at the rear of the platform. Thus, as the carriage recoils, the compressors, recoiling with it, and being fixed apart at a constant distance, carry with them the sheet india-rubber or steel spring, which undergoes a gradually increasing compression or deflection as the baulk increases in width; the pressure, and therefore the resistance, increasing proportionately. Another method of checking the recoil, and one which has been generally introduced with great success, is by means of the resistance offered by a considerable body of water, or other fluid, when forced through a small opening. The contrivance was originated by Colonel Clerk, of the Royal Artillery, late Superintendent of the Royal Carriage Department. It commends itself on the grounds of simplicity and effectiveness, consisting merely of a piston, G, (Figs. 5, 6) attached to the bottom of the carriage, having four holes of about an inch in diameter in the piston-head, the diameter of which is about eight inches. This works in a cylinder, H, fixed along the centre of the platform, and which, being otherwise closed at both ends, is nearly filled with oil. On firing the gun, the recoil forces the piston-head against this confined mass of oil, which can only make way for the progress of the piston by escaping through the openings in its head, thus presenting a great resistance to the motion of the carriage with which the piston is connected. This resistance, unlike that of the frictional compressors, is greatest almost at the first instant, and rapidly decreases, varying with some power of the velocity of recoil, probably between the square and cube of that velocity. A merit possessed by this "hydraulic buffer," as it is termed, is the superior regularity of the resistance offered by a fluid compared with the resistance due to the friction of two solid surfaces.

After each recoil of the carriage, the gun is in a convenient position for loading. This process completed, it remains to be considered what facility is offered for running the carriage forward into the firing position. The carriage in its usual position is supported by the platform, on which the brackets rest along their entire length. In recoiling, very great friction is set up between the touching surfaces of the carriage and platform. This friction materially assists in bringing the carriage to rest. The resistance may be estimated at one-tenth of the weight moved. The 9-inch gun and its carriage weigh about 15 tons, consequently the resistance due to friction will be about one ton and a half. Useful as this is in recoil, its action presents a serious obstacle to running up the gun into the firing position, which would have to be accomplished by manual labour. The difficulty is overcome by the simple expedient of raising the sides of the carriage off the platform, and supporting them on rollers, L L (Fig. 4). The front rollers are so attached to the carriage, that they shall, under ordinary circumstances, be just clear of the platform. The hind rollers work on eccentric axles, so adjusted that until the eccentric axle is turned round by a lever inserted in the socket N, which is rigidly connected with the axle, the roller takes no bearing on the platform. When that operation is performed, however, the rear rollers raise the whole carriage, bringing its front portion on to the front rollers. The carriage is then, for the time being, on four wheels, and its gravity acting down the slope of the platform impels it towards the front.

The various contrivances now described provide for the heaviest guns being controlled effectually and rapidly.

With reference to the third condition, a few words must suffice. Artillerists have long directed their attention to the object of securing the best possible cover for gun, carriage, and men. Three distinct methods have been suggested. The first by reducing the size of the embrasure to its smallest possible dimensions. With this view, the system of racers, with imaginary pivot under the muzzle of the gun, was introduced, admitting the use of a narrow but high embrasure. This has been in some cases greatly reduced in height by the introduction of muzzle-pivoting carriages, several varieties of which have been tried; and some few are adopted for service in naval turrets. The distinctive feature of these carriages is that the gun receives its elevation and depression partly or entirely by moving the trunnions down or up, while the position of the muzzle remains stationary. The second method is that of utilising the force of recoil to raise an iron shield in front of the embrasure. This has never been adopted, but seems practicable and well deserving a trial. The third method is that of having a very high parapet, over which the gun fires, and under cover of which it is loaded. The very ingenious invention of Captain Moncrieff, now so well known, is at present the only successful representation of this method. In his system he utilises the force of recoil to bring the gun under cover; and by the action of a counter-weight restores it to the firing position.

SANITARY ENGINEERING.—XI.

WARMING BY HOT AIR AND STEAM.

In this country the warming of apartments, as a general rule, is by an open fire. Up to the time of the Tudors, the usual method was an open hearth, wood being the fuel; and the large, handsome fireplaces of the period were all provided with dogs, as they were called—*i.e.*, iron frames at either end of the hearth upon which the wood fire was kindled, to support the logs as they were thrown upon it: and in France, at the present day, the same system may often be seen in operation. Flues or

chimneys, for the removal of smoke, were not generally provided in this country till about the fourteenth century, the smoke finding its way out by openings provided in the roof as best it might. In some old baronial halls the fire-place occupied the centre of the apartment, an opening immediately over it in the roof allowing the smoke to escape. The blackened rafters of some of our old mansions show clearly in what a state of atmosphere during the winter many of our ancestors must have passed their time.

On the Continent, however, the comparative scarcity of fuel in many districts, and the extreme cold of others, early led to the introduction of the hot-air stove, in which the heat is obtained, not directly from the fire, but by radiation from the heated surfaces of the stove itself, within which the fire was contained, and which frequently, for cleanliness and convenience, was so arranged that the fuel was supplied and the fire attended to from another apartment. In Germany, Sweden, and Russia this form of stove is still in constant use, and in many other parts of the Continent; the materials used in their construction vary with the district, but we may mention, as those most in use, sheet iron and glazed tiles. The objection to the use of iron is that if the stove is allowed to become heated beyond a certain point, the air is, as it is technically called, burnt, and becomes unwholesome, headache and similar ailments frequently affecting the inmates: some remedy, however, is found by placing an open vessel filled with water upon the top of the stove, the moisture communicated to the air by its evaporation materially controlling unwholesome effects.

The method upon which these stoves are usually built is this: the fire has only a small opening to the external air—indeed, it rather resembles a furnace than a fire—and the flue is conducted, through a series of what may be called convolutions, around and, as it were, in the body of the stove itself. A very common construction is to have four flues, vertical, one at each angle of the central space which contains the furnace, from which they are separated by brick or other divisions; the smoke is then conducted up the one and down the opposite one alternately, until the whole circuit has been made, and it ultimately passes off into the chimney proper. The whole mass of brickwork is raised to a considerable temperature, and the radiated heat thus obtained does the work. That there is no doubt as to the salubrity of these stoves when properly worked we may take for granted, as they have been made the subject of comment and experiment by some of the first scientific authorities on the Continent.

So much for the general principle of foreign hot-air stoves. We proceed to describe one of the best and most extensively used stoves of this description used in modern times, known as Dr. Arnott's, the objects of special study in its construction being the wholesomeness of the atmosphere warmed, and economy of the fuel by which the result is obtained. A double case of iron is provided, in the interior of which is the pan or stove, made of earthenware, which contains the fuel, the coal burnt being anthracite, or some similar slow-burning quality. A constant circulation of air is kept up between the outer and inner case of the stove, which retains the outer case at a moderate temperature, while the products of combustion, of small volume, are conveyed by a pipe to the nearest chimney or to the open air.

The fire is supplied with air by a small opening, closing by a valve, which is made self-acting by different ingenious contrivances—*i.e.*, when the stove becomes too warm the valve partially closes, and the draught is controlled. Sometimes this result is attained by the use of two bars of different metals, brass and iron, the unequal expansion being utilised to effect the desired result; sometimes air confined in a glass tube by quicksilver is made by its expansion to produce a similar result. Dr. Arnott made these inventions the subject of a lecture at the Royal Institution in 1836.

Another system was also introduced in London some years ago, by which the kitchen fire was made available for heating all the rooms of the house. A large hot-air chamber was constructed at the back of the grate, in which the air was heated to a very considerable temperature; it was then conducted by flues, somewhat on the same principle as described in our last paper on "Warming by Hot Water," to the topmost storey of the building, and subsequently distributed by circulation and separate flues to the various rooms where the warmth was required.

In some large buildings a somewhat similar principle has been adopted, the air being heated at a furnace specially designed for the purpose, and afterwards forced by a fan or blower driven by a steam-engine through a series of flues in various directions.

A combination is often made of the open fireplace and the close stove, with advantage, by the following means:—The fire is surrounded at the back and sides by an air-chamber, which has no communication with the smoke-flue, but has a small pipe or other duct communicating with the external air. The fresh air thus drawn in by the heat of the fire is admitted directly into the room to be warmed, by openings in the front of the grate, which may either be plain, or protected as they generally are by open ornamental perforated gratings. One advantage of the adoption of this system is that the hotter the fire and the quicker the draught the greater is the body of fresh air supplied to the room, the air being already warmed by its passage through the chamber at the back of the grate.

Hot-air stoves of various constructions have recently been heated by gas; these are generally adopted in small rooms, where the situation is confined, and the construction of the building does not admit of the introduction of an ordinary fire-place. They are made with outer cases, sometimes of iron and sometimes of porcelain; a ring of gas at the bottom heating a constant current of air passing through the stoves. In some cases provision is made, by pipes or otherwise, to remove the products of combustion; but when the room is of moderate size and tolerably well ventilated, they may be allowed to mingle with the air of the room, and so become dispersed, without any unpleasant effect; as they are in point of fact no more in volume than those produced by a few ordinary jets as used for lighting purposes. We may here repeat what we before alluded to in our paper on "Cooking by Gas," that the most economical method of consuming it when heat, not light, is the object in view, is by admixture with a certain per-centage of atmospheric air, and most of our best modern gas stoves are constructed on this principle.

The varieties of requirements are so great in ordinary warming by hot air, and the methods of application so various, that we do not think it worth while to give any general data for exact calculation; the size of the room, the uses to which it is to be adapted, and the temperature required, leaving an opportunity in practice for almost infinite variety in the means to be selected.

We now approach the next branch of our subject, warming by steam. This is rarely adopted in dwelling-houses, unless their proximity to a factory where there is steam-power gives facility for its introduction. The means adopted are pipes, sometimes of cast iron, sometimes of wrought, according to circumstances; care, however, being always taken that they are sufficiently strong to resist the pressure to which they must necessarily be subjected—generally the working pressure of a boiler, high or low, as the case may be; the temperature, of course, materially affecting the proportional quantity of pipe required to heat a certain number of cubic feet of air. The general principle, however, we have explained in our previous paper on "Warming by Warm Water;" and we may say that, as a general rule, steam occupies an intermediate place between the two systems, as it is not generally necessary to provide for such excessive pressure as when the high-pressure system of hot water is adopted pure and simple, this being to a certain extent a speciality, as described in our last.

In many cases, however, steam has been adopted as a method of warming when distributed through pipes, though mostly for commercial as distinguished from domestic purposes, and we may, therefore, note some practical points which are worthy of attention when this system is adopted for heating purposes only, and is not merely an adjunct to an existing steam-boiler. For simplicity, economy, and efficiency combined, the old wagon-head boiler to a great extent holds its own, and it should always be borne in mind that steam is most economically and rapidly generated when the feed to the boiler is hot. This result is readily obtained by arranging the feed-cistern in such a position that the smoke and waste heat from the fire pass round it, and the water may be thus heated before passing into the boiler at a heat little short of boiling. Too great a body of water in the boiler is also objectionable, as the time consumed in heating it to boiling-point and generating steam wastes time and fuel.

It is always desirable, if possible, to have two boilers, primarily

to provide a reserve in case of accident, and also to give facilities for alterations and repairs. Another point to be carefully attended to is a regular draught of air, so as to ensure a perfect combustion of fuel, and the evolution of a maximum of heat; a too rapid draught is often wasteful, as it draws the heat up the chimney, instead of allowing it to do its full work upon the boiler. In slow-burning coals it is especially wasteful, while in quick fires it is sometimes an advantage. In all constructions where steam is employed, the safety-valve forms a necessary part of the fittings; and the pressure at which the apparatus is to work being arranged, a periodical investigation of its being in proper working order is the duty of the engineer. As to the material for the pipes, lead is inadmissible for this reason, that at the temperature of boiling water it expands beyond its power of re-contraction, and therefore any attempt to use it in permanence either for boiling water or steam will certainly be followed by buckling and failure. Copper is expensive, and also unhealthy, being sometimes offensive in smell when heated. Zinc is too brittle, and oxidises rapidly at high temperature: we are, therefore, driven to the selection of wrought or cast iron, as occasion or economy may suggest the employment of the one or the other. The necessary provision should also be made for the expansion of the pipes when heated; for this we have already given sufficiently accurate data in our paper on "Warming by Warm Water."

In a previous paper on "Warming by Hot Water" we gave a caution as to care requisite in arranging the level of the pipes so that steam should not be allowed to accumulate and be confined in the upper levels, and thus interfere with the circulation. In the use of steam-pipes the converse difficulty arises, and precautions should be taken to prevent the condensation and accumulation of water in the lower levels, as it will not only interfere with the circulation, but in some cases, by sudden condensation, accidents have occurred. It is desirable to have the pipes so arranged, as to level, that when out of use the condensation, as it accumulates, may be drawn off by means of stop-cocks.

In applying steam to the heating of public buildings, allowance must always be made for the loss of heat from window openings, or surfaces of glass of any kind. There have been various methods of calculation adopted, but as our space will not allow us to give them in detail, we content ourselves with quoting a single example from a well-known authority. The temperature of a church seating 1,200 people, and containing 100,000 cubic feet of space, taking the average congregation at 600, and allowing 1,000 feet of glass surface, has to be kept up to 60°, supposing that of the external air to be 30°. The quantity of superficial surface of steam-pipe required will be 428 feet; and to produce this result the boiler should be in full work somewhat less than half an hour before the building has acquired the requisite temperature: to attain this result the fire must, of course, be lighted a proportional time before. If the pipe be 4 inches diameter, as the girth is as nearly as may be one foot, the length required is at once ascertained; and, with certain allowances for friction and radiation given in a former article, the quantity of any other dimension of pipe can be readily ascertained: and it is a common rule to adopt that the boiler should contain sufficient steam to fill the whole of the pipe—in this case 37 feet.

In heating mills, a higher temperature has often to be maintained—70° is not uncommon; but by a careful attention to the rules laid down for proportion of window-space, ventilation, etc., an accurate calculation can be made of the quantity of heating surface, the amount of boiler-space, the area of the fire, the quantity of fuel, and all similar points.

Many manufacturing businesses of the present day are carried on by means of machinery driven by steam-power. The last generation has witnessed a wonderful extension of the principle. In many trades where thirty years ago steam was hardly thought of, it is now one of the main adjuncts in the conduct of the business. This is most especially the case in all matters connected with wood manufacture. Cabinet-makers, joiners, musical instrument makers, and a host of other trades are all carried on by steam-power, and here the boiler required for the conduct of the business requires little additional size to provide the requisite convenience. The loss of power accrues only by the cooling of the surface of the pipe exposed to the air, and can easily be calculated; and the heat used for warming may be utilised for many trade purposes, seasoning timber, heating glue, in other trades heating irons of various descriptions, and many other purposes.

The limits of our space do not allow us to do more than allude to the many auxiliary purposes to which heat may be applied by steam-pipes. The drying of woollen, muslin, and other fabrics, and many other trade processes, can be carried on at small expense by a series of steam-pipes connected with the working boiler of the establishment.

One familiar instance we may quote: the danger of fire in building establishments is well recognised, and the prices charged for insurance by the offices, as all contractors know, are, as a usual rule, exorbitant. When there is a steam-boiler on the premises, a judicious arrangement of a system of pipes will not only keep the shop up to a requisite temperature at a minimum expense, but may be made available for melting glue—a steam-chest for the purpose being provided—boiling water, and all ordinary heating requirements; and in many other trades where heat is required and steam is available, similar results may be obtained by a comparatively moderate outlay.

CHEMISTRY APPLIED TO THE ARTS.—XIII.

BY GEORGE GLADSTONE, F.C.S.

GLASS-MAKING.

Silicon, the essential element of flint, quartz, and rock crystal, will, at a high temperature, enter into combination with the oxides of several of the metals and earthy elements, forming a silicate, which, on cooling, becomes an amorphous transparent substance, to which the name "glass" is applied.

The quality and appearance of the product differ very considerably according to the materials used in the preparation; so that in classifying the various sorts of glass, the difference in the ingredients as well as in the mode of manufacture will have to be taken into consideration.

The two most familiar forms in which glass is presented to us, are in bottles, from the common dark green one used by the wine or beer merchants, up to the elegantly moulded and cut carafe; and in windows, where the difference is almost equally great between the little bull's-eyed panes of an old cottage and the large polished plates which adorn the modern West-end houses. It will be convenient to follow these two grand divisions, alluding, by the way, to other descriptions of less general importance.

We begin with green bottle-glass, in which the commonest materials are used, and the simplest process is adopted, as cheapness is an important consideration in this manufacture. The ordinary ingredients for this description are ferruginous sands, yellow marl, and cullet (which is glass waste from former meltings), with some kelp or wood ashes, or the residues from the soap and soda works. The sand and marl will both supply silica and oxide of iron, and the marl, lime and alumina in addition, while the ashes or soapmaker's waste will furnish potash or soda. The relative proportions of the several ingredients vary considerably in different factories, but the weight of the alkalis should be something more than double that of the sand and marl together. The iron contained in the two latter facilitates the combination, as it acts the part of a flux; but to it is due the dark colour common to this sort of glass. Sands entirely free from the presence of this metal are rare, and therefore expensive; they are consequently reserved exclusively for the manufacture of colourless glass. Before use the sand is dried, and then sifted to remove any extraneous substances; the clay or marl is also thoroughly dried and reduced to the state of powder; lime or chalk, treated in the same way, is often substituted for the latter if the sand employed is argillaceous in character.

The materials being all intimately mixed together, are put into the melting-pots to be fused. These are large vessels made of clay, open at the top, and tapering slightly downwards, so that in shape they resemble very closely a common garden pot, only that they have no rim. In size, those used for crown or plate glass-making are about 4½ feet high, 3 feet in internal diameter at the base, widening to 3¾ feet at the top; but in the special manufacture we are now describing, they are usually made smaller, being about 3 feet in height, and the same in extreme width. As the making of the pots themselves forms a part of the business of the glass works, and the success of the

establishment depends in no considerable degree upon the care exercised in their manufacture, we must pause for a moment to describe this operation.

The very best Stourbridge or other refractory clay should be used in making pots; the nearer that it approaches to a pure silicate of alumina the better, but the presence of lime and pyrites is especialy to be avoided. The clay should be moistened with water, and thoroughly kneaded with some old pot finely ground, until its composition becomes thoroughly uniform. It is then rolled out into small lumps, and these are used for building up the pot by being pressed intimately together by the hands of the workman, whose great care is not to leave any air-bubbles between them. The pot is then transferred to the drying-room, which is kept at only about a full summer heat, and it is left there for many months to dry. When ready, and required for use, it is removed to a reverberatory furnace to be annealed, when in the course of several days it is very gradually warmed up to a bright red heat, and while at that temperature it is rapidly transferred to its ultimate position in the glass furnace. When it has been there a sufficient time to have got up to its full heat, it is glazed by throwing in a little cullet, and is then ready for use.

A very intense heat is required for fusing the mixture which has already been described; and therefore, with the object of economising fuel, the furnace is so constructed as to heat several pots at the same time, the fire-place being in the centre with the pots around it. The draught is supplied from a vaulted chamber beneath the floor of the glass-house, in the arch of which the fire-bars of the grate are placed. The furnace is covered above with a vaulted roof enclosing the pots, the flues being so placed that the heated gases must pass all round the sides of the pots before they can escape up the common chimney.

The pots are filled up with the mixed materials, which gradually sink down as they melt; more is then added until the pot is nearly full of melted "metal," as it is always called by the workmen. During the melting the carbon which may be present in the clay or alkali is converted into carbonic oxide, the ebullition caused by the escape of which gas greatly facilitates the intimate mixture of the several ingredients, and so prevents the glass from presenting a streaky appearance. This is a matter of special importance when preparing the finer qualities; and in order to aid the escape of this gas, without which the glass when made will be found to be full of bubbles, the greatest possible heat is maintained for a short time, so as to render the metal quite limpid. After this the fire is lowered so that the glass may thicken again into a viscid mass, and thus become in a condition to be worked.

The more mechanical part of the process—that of giving the glass a form—is now arrived at, and it will here be necessary first to describe the principal tools and appliances used by the glass-blower and his assistant. The most important of all is the pipe, a hollow iron tube about 4½ feet long, with a mouthpiece at one end and a small knob at the other; a solid iron rod of about the same dimensions, called a punty; different forms of tongs made with a slight spring, after the fashion of those used for handing sugar at the tea-table; a large pair of scissors; an arm-chair, the arms of which are quite straight, and extend for some distance in front of the seat; and a low table, the top of which consists of a slab of polished iron. In addition to these, moulds of various shapes are generally used, in order to secure uniformity in the size and shape of the bottles produced.

The pot having been skimmed of the impurities (called glass-gall or sandiver) which will be found floating upon the surface of the metal, the end of the pipe (having first been heated) is dipped in, and a quantity of metal is gathered round the knob, sufficient to produce the kind of bottle that may be required. The blower then takes the pipe, and blows down it into the metal, which will thus assume a hollow balloon shape; by rolling it upon the table he flattens the sides; with the tongs he compresses and shapes the neck, rapidly twirling the pipe round at the same time by rolling it upon the arms of his chair with his left hand; and then he puts it into the mould, and blows into it again to give it the final shaping. The bottle so far made is then taken up by the finisher by applying the punty, tipped with a little hot metal from the pot, to the bottom of it; and then it is detached from the pipe by the touch of a piece of cold iron or a little water. The finisher then re-heats the neck of the bottle at the working hole of the furnace, as by this time the metal has considerably cooled down; shapes the neck properly inside as well as outside, and taking a small piece of fresh metal he twists it round the top and completes the rim. The bottle is then carried off by a boy to the annealing oven to cool, and by a slight jerk it is disengaged from the punty.

The whole operation has of necessity to be done very quickly, and a rapid rotatory motion has to be maintained throughout, in order to prevent the glass from collapsing, or even dropping into an oblique form, in which case the bottle when finished would not stand upright. Rotation round the pipe as the axis will tend to make the bottle wide and flat; if a long and narrow form should be required, the workman can readily produce it by holding the pipe at the mouthpiece, and swinging it all bodily round in a large circle with his shoulder as the centre.

Many bottles are made without the use of a mould, in which case the process is precisely the same as that detailed above, with this single exception—the blower judging by the eye as to the size and form to be given to it.

The annealing oven yet remains to be described. Were the glass to cool rapidly it would be so extremely brittle as to be absolutely useless, and thick glass especially would be liable to fly to pieces, in consequence of only slight changes of temperature. The reason of this seems to be pretty apparent, and the cure simple and effective. Like other substances glass contracts in cooling, though relatively less so than most of the metals; as compared with them, however, its conductivity for heat is singularly small. Although, therefore, the relative contraction of iron and glass is, in round numbers, as 3 to 2, we can understand that the superior conductivity of iron admits of a molecular change throughout its mass taking place during the cooling, sufficient to prevent the various parts from being at very different states of tension. Glass, however, is such a bad conductor, that the exterior portion will be cold and rigid while the interior is still hot, and therefore expanded; as it cools, then, the cohesion of the particles will become weaker as the centre is approached, and the state of tension to which the whole will be subject will naturally render it sensitive to the slightest external influences.

The annealing oven is therefore so constructed that the greatest heat shall be near the door through which the bottles or other glass wares are passed in, with a gradual reduction in temperature towards the door at the other end where the goods are taken out. These ovens are frequently made in the form of a long low archway, sometimes sixty feet in length, with a furnace at one end only, where the heat is almost sufficient to melt glass. Here the goods are inserted, and the draught is directed through the tunnel, so that the parts more remote are only heated by the surplus heat from in front; the glass is made to pass slowly through the tunnel, the trays on which it stands being worked by an endless chain, and the speed being regulated according to the kind of goods to be annealed.

For small phials and the ordinary colourless glass, more care is taken in the selection of the materials, any containing iron and alumina being carefully avoided. Fine white sand, well washed, is used, with potash, soda, lime, and white cullet. A little oxide of manganese is often added, to assist in the oxidation of any ingredients which might otherwise give a shade of colour to the glass.

That quality, however, which is known as flint glass or crystal, and which includes all the ornamental colourless cut ware, has quite a different composition. It is a double silicate of potash and lead. The presence of the lead salt greatly heightens the brilliance of the glass, renders it more readily fusible, and softer. The use of soda is always avoided, because with lead it will impart a slight tint to the glass. The double silicate of potash and zinc is also found to have the same properties; but the manufacturers generally adhere to the more familiar combination. The most approved proportions are:—

Carbonate of potash	1 cwt.	Nitrate of potash	14 to 28 lbs.
Oxide of lead	2 ,,	Oxide of manganese	4 to 12 oz.
Burnt sand	3 ,,		

to which pure flint cullet can be added at discretion.

A much lower temperature will suffice to fuse this mixture; and advantage is taken of this circumstance in using covered instead of open pots, by which the risk of any impurities falling into them during the melting is entirely obviated. A larger number of pots can also be heated with one fire; ten being found the most desirable number.

The greatest possible care has to be taken that all the ingredients are as pure as they can be made. The lead salt is specially prepared for glass-maker's use. The best white sand from Alum Bay or Lynn Regis is first washed several times, and then burnt, to remove all chance of impurities. The carbonate of potash is dissolved and re-crystallised, with the same object. From such ingredients a pure metal will be obtained, without even any sandiver floating on the surface, so that the operation of skimming has not to be performed.

The mechanical operations of blowing and shaping the molten glass do not differ in principle from those already described; but are subject to almost endless modifications in practice, as may be judged from the variety and complexity of the forms in which the manufactured article is presented to us on the home table. It is unnecessary to go into these in detail.

Many articles, such as tumblers, fruit dishes, etc., are simply moulded, and are often sold without being subsequently cut and polished. These at once show their origin, by the undulation of their surface, and the clumsiness of their edges: they are, of course, much cheaper than the properly finished article.

Flint glass is cut or ground by being brought into contact with discs of metal or stone which revolve on a lathe. The face or edge of the discs is varied according to the form of cut required; and fine sand or emery mixed with water is supplied to the grinding surface from a hopper above, the former for rough work, and the latter for fine grinding. For polishing, a wheel of stone is first used to take out the coarsest scratches; and then one of willow wood dressed with rotten stone, and subsequently, for the finest work, with putty powder.

PAPER AND CARDBOARD MAKING.—I.

BY GEORGE TINDALL.

MATERIALS.

The history of paper-making is the history of civilisation. From the time when man began to advance from the most primitive state, the necessity of some vehicle to convey his thoughts and ideas otherwise than orally would be felt, and the conveyance of those ideas by signs would necessitate the use of some substances on which these signs could be exhibited; and we may be sure the carving of these signs upon such natural substances as first present themselves, such as wood and stone, would be too tedious and laborious a process not to call for some effort to produce a medium which would give greater facilities for the more rapid interchange of thought. Hence we find that from a very remote period paper made from leaves, pith, and other crude vegetable substances, was used; but the elimination from these substances of their fibres, and the working of these fibres into thin plates or sheets upon which symbols could be portrayed, is a much later invention among Western nations; although the Chinese seem to have made paper from cotton, and mixed materials, as bamboo, hemp, and rice-straw, from very early times. The Egyptian papyrus, from which we derive the word *paper*, was made from a reedy plant formerly growing in large quantities in Egypt, but the art has now entirely disappeared, and of the character of it we have no certain knowledge. The substance is supposed to have been made either by placing thin slices, or the thin concentric coats separated by means of a needle or pointed shell, in layers, and pressing these together whilst moist; they were afterwards dried in the sun, and polished by burnishing with a tooth, or some other hard substance.

The materials from which pure paper is made in the present day are entirely *vegetable fibres*. Any kind of these fibres may be converted into paper, but not all of them possess the necessary qualifications of being easily separated from the remaining portions of the plant, and the capability of being bleached sufficiently to fit them for use in the finer kinds of paper, as "writings" and "printings;" hence comparatively few have found favour with paper-makers; indeed, the use of vegetable substances for direct conversion into paper has only resulted in consequence of the enormously increased demand for that article, which has been felt since the abolition of those so-called "taxes on knowledge," which formerly considerably augmented the price of paper. Prior to this time, manufacturers were content to procure their materials at second hand, either as waste products, obtained during the conversion of vegetable fibres into more costly fabrics, or from those fabrics themselves, after they had been used for the purposes for which they were originally manufactured. Hence materials for the manufacture of paper may be divided into

(*a*) Vegetable tissues which have undergone previous preparation in other manufactures.

(*b*) Crude vegetable tissues.

Of the first of these classes, those tissues which have undergone previous preparation, rags are by far the most important; as for a long time—indeed, so long as the supply was equal to the demand—they formed almost the only materials used in the manufacture of paper. The comparative ease with which the process of reducing them to pulp could be performed was, doubtless, another reason for this preference, for they only require cleansing from dirt mechanically adherent; whilst crude vegetable fibres, in the first place, require very considerable "cooking" to free them from the gums, resins, and other substances with which they are so intimately associated in the tissues of plants. Rags, too, from the frequent washings to which they are generally subjected whilst being worn, are bleached much more easily, and at less cost.

Rags are of very various values as paper materials. Cotton rags, for instance, produce a soft woolly paper, which takes a smooth surface easily, and is very suitable for printing purposes; whilst linen rags produce a hard, strong paper, which makes them more suitable for writing on, and it is from new clean linen cuttings and rags, when made by hand and dried slowly in the air, that our finest and strongest account-book papers, bank-notes, loan-papers, etc., are made. Both these kinds of rags bleach easily, and are in great request. Hemp rags, too, especially in the shape of sail and other canvas, although they do not bleach so readily as linen, form an excellent hard material, and are very useful mixed with cotton for printings, making them firmer and stronger.

Other kinds of rags vary in degree of hardness, and it is by the careful use and admixture of these and other substances that the various kinds of paper are produced, so that it will be at once seen how important to the paper-maker is a knowledge, in the first place, of the properties of the various fibres which come under his notice. Rags, as collected, are of course of a very mixed character, and are to some extent sorted and classified by the dealers. The qualities are somewhat numerous; superfines and fines, consisting entirely of white rags, are used for writing paper; outshots and seconds, or dirty fines, are the same kind of rags, but well worn, and consequently unclean, and may be used for fine printings; prints, which are sufficiently defined by the name, may be either clean or dark, according to the amount of wear or use they have undergone; they are good cotton rags, but the colouring matter printed on them must be discharged; whilst thirds are the dirtiest cotton and linen rags, and only useful for the lower qualities of printing and wrapping papers. Besides the home supply, large quantities of rags are imported from the Continent, and from Egypt, India, and other countries, these being known by various letters and marks; the same kind of rags from different countries being very different in value, and most of them being softer and weaker than English rags. The character of the neighbourhood from which rags are collected, too, is of some importance in estimating their value, country rags being always cleaner than those from the neighbourhood of large manufacturing towns. The fustians and corduroys of the agricultural labourer are *light*, and those of the factory operatives are *dark* and greasy, whilst the particular kinds of manufacture prevailing in certain districts affects the rags collected in the neighbourhood.

Besides the used-up results of the cotton and linen manufacture in the shape of rags, another large class of materials is produced during the manufacturing process, called *waste*, and this usually consists of short fibres and other impure substances cleaned from the good fibre in the various processes. Cotton waste is so valuable for cleaning marine engines and other machinery, that very little of it except of a very inferior quality finds its way to the paper-mill; but the waste from some branches of cotton manufacture, such as thread, candlewick, etc., when clean, are excellent and easily worked materials. Flax or linen waste, however, is very largely used, and the cleaner portion forms an excellent hard material for mixing with softer rags, and giving strength to papers of medium quality. The commoner kinds of this waste, such as tow, are very impure,

being full of "sheaf," the outer coating of the flax stem, which no amount of "willowing" will eliminate, and which not being acted on by the bleaching agent in the same manner as the rest of the fibre, shows up as small elongated yellowish specks in the paper. Large quantities of this material are now imported from the Continent.

Hemp and jute also enter largely into the manufacture of paper, especially of the commoner kinds, in the shape of ropes, bagging, and waste. For a long time, brown papers were made almost entirely from old ropes, and those made from this material have still the pre-eminence in the market. Hempen ropes and twines bleach well, but they are now so seldom found except mixed with jute and other substances, which are very difficult to bleach, that they are rarely used except for inferior papers, but they are all good strong materials for this purpose; so are the various kinds of bagging which are made from the same substances, and two of which enter very largely into the manufacture of paper, viz., "Surat" bagging, or the sheets in which cotton is packed when sent from America, and "Botany" in which wool is sent from Australia. Manilla hemp is also a very strong tough fibre, from which some of the most tenacious thin glazed casings are made; these are almost as strong as parchment, and are very serviceable for wrapping iron and steel goods. This material is also used in America for writings, although it is difficult to bleach.

From what we have said above, it will be seen that woollen rags are not suitable for the paper-maker, and for white papers they are carefully sorted out and discarded; but it is well known that most woollen cloths are made from a mixture of wool and cotton, the longitudinal fibres or "warp" being of the latter substance; and as wool is easily destroyed by a solution of caustic lime, these rags are now used to some extent by the makers of purple sugar and other coarse papers, the wool being partly destroyed in the boiling process. As, however, woollen rags can be converted into shoddy and mungo, and used again for the manufacture of woollen cloth, it is not very likely that the use of these rags in the paper trade will be largely increased.

Of late years the use of waste papers for re-manufacture has very rapidly extended; so much so that the collection of these papers is now a very considerable industry. Brown, coloured, and even printed papers are all used, the ink being discharged from the latter by boiling in a solution of caustic soda, and this waste now enters largely into the composition of news and the commoner kinds of printings, as well as all the inferior coloured papers. Large quantities of waste papers are also regularly exported to the United States.

Besides these, many other waste substances enter largely into the manufacture of the commoner papers; sugar matting, old fishing-nets, woollens, and even silks may be used where white papers are not required; but the increased utilisation of these substances by re-manufacture into fabrics of a more costly character gradually narrows the quantities of these materials available for use by the paper-maker, and makes him fall back more and more on a different class of substances.

We shall now proceed to describe the second division of paper materials—crude vegetable fibres. Esparto, straw, and wood are at present the only substances really competing with and supplementing the use of rags. Other fibres are being tried, or being used in small quantity, and doubtless the time is not far distant when the vast forests of the tropics, where vegetable growth is so rapid and luxuriant, will furnish abundant materials to supply the enormously augmented demand for paper caused by the increasing intelligence of the age. At present the colder regions of the earth seem to be likely to be first in the race, and the vast forests of Scandinavia are being attacked for this purpose; but the requirements of the paper-maker are ever increasing, and the want is still felt of a material to help the limited though large supplies at present available.

Esparto, originally introduced from Spain, is a coarse, strong, and rush-like grass, growing in large quantities on waste lands bordering the Mediterranean, and was until recently only used for ropes, matting, etc. It is, next to rags, by far the most important material used by paper-makers, and, properly treated, it produces a beautiful, clean, transparent paper, with a soft silky surface, well adapted for printing and lithography. It bleaches a warm creamy white easily, and the process may be carried on until it rivals snow in purity and brilliancy. It is now very largely used in the manufacture of news and fine printings, and very cheap and good writings are made entirely from it, or with the admixture of rags. It is more difficult to reduce than rags, requiring a strong solution of caustic soda for the boiling process; and as only the fibrous portion of the plant can be used, the yield is not nearly so great as from rags, where the waste has been previously got rid of. It requires more than two tons of esparto to produce one ton of paper—a most important consideration when esparto rises, as was recently the case, in a very short time from £6 to £10 per ton. Large quantities of this grass have of late been imported from Algeria, and a small quantity from other portions of the Mediterranean coast, but the Algerian fibre is more difficult to work than the Spanish, and the former still maintains a considerably higher price in the market. Many paper-makers are of opinion that the quality of the fibre has deteriorated of late years, the choice growths being first picked, whilst the plant requires some years to come to perfection; it is certain that very inferior qualities have recently been brought to the market, but these have been eagerly bought for common news, the demand for which has become enormous. The bulk of the esparto imported to England was, until very lately, brought as return cargo to Newcastle by vessels laden outwards with coke for the Mediterranean ports, and the North Eastern Railway Company built large sheds at Tyne Docks for its reception; these, however, soon became too small for the rapidly developed traffic in this grass, and it is now stacked in the open air, and thatched like ricks of hay. The stock of esparto at Tyne Docks has often been from 15,000 to 20,000 tons, whilst the annual import has reached 100,000 tons; this is, however, now sent to many other ports besides Newcastle, principally to Leith, Cardiff, London, and Liverpool, in order to accommodate paper-mills in various parts of the country.

Straw has for many years been largely used in Germany and other Continental countries, for the manufacture of millboards and coarse brown wrapping paper; but lately the treatment of this substance has been very greatly improved in England, and now a clean white printing and fair writing paper is produced from it. There is, however, one great drawback to its use for the higher qualities of paper—the product is always tender and brittle; but mixed in small quantities with other substances it forms a hard material, and gives bulk and handle to otherwise soft and woolly papers. For clean white papers, only oat or barley straw is used, wheat straw having hitherto proved too refractory for use in these qualities. The principal difficulty is the reduction of the knots; the other portions of the stalk are more easily reduced than esparto; but unless the knots are completely softened by thorough boiling, these portions do not bleach uniformly with the rest, but show as "sheaf" in the paper. The attempt has been made to separate the knots by cutting the straw to chaff and winnowing, but without success, from the very small difference in the weight of the two portions. A machine has also been used for pressing the knots between rollers, and thus breaking them up, but this method was equally unsuccessful, and both have been abandoned. In those mills where the best straw papers are made, the straw is first cut to chaff and then boiled by steam at a high pressure, until thoroughly "cooked;" the knots are then sufficiently digested to bleach equally with the rest of the material. Straw millboards are now largely used in England for all light bookbinding purposes, and almost universally for cloth cases for printed books, and also for box-making. They are easily cut and worked, and are suitable for all purposes where strength is not of importance.

Wood promises to become very shortly as important a material to the paper-maker as esparto, although at present the product is very inferior; still, the improvements which have very recently and are now being made seem to show that it is capable of producing good fibre, but the processes are costly in comparison with esparto and straw. With the exception of a few mills, this material is only used in England, and that in the shape of wood-pulp imported from the Continent, principally from Sweden and Germany, where the raw material is cheap and plentiful. In the manufacture of this pulp the wood is ground to powder, and hence there is a want of staple in the fibre, so that it can only be used to mix with other materials, and in this state it is almost impossible to bleach to a good colour; it is used chiefly in the manufacture of inferior news and printings, in order to fill up the engines and reduce the proportion of esparto. Large quantities of news made entirely

from wood have of late been imported from the Continent at a considerably less price than English-made printings; but this having no fibre, is as a rule tender, and wets unevenly, so that it takes a very imperfect impression when printed, and has consequently not been able to maintain its own against paper made from other materials. Other attempts are now being made, and so far with considerable success, to treat wood so as to retain the fibre of some length, by crushing, and a variety of other processes; the pulp produced by this means bleaches well, and the paper manufactured from it is of good quality, and very suitable for printing purposes.

Various other crude vegetable substances are used in small quantities, or at present form the subject of experiment. One of the most interesting of these is the outer husk of the cotton seed, which in great quantity has hitherto been a waste substance, or used only as manure. The use of this material is adopted in conjunction with another manufacture, viz., the obtaining of oil from the kernel: the seeds are crushed in a machine between rollers, and the kernel separated from the husk, which is then boiled in a strong solution of caustic soda: this separates the fibres from the hard portion of the husk. A paper of medium quality, but not very good colour, is the result. Palmetto, or the leaves of the dwarf palm, which grows in great abundance in some parts of the African continent, has latterly been imported in some quantity: the stalk and ribs of the leaf are very hard and strong, and require treating differently from the connecting leafy portion, which must be cut out with scissors, so that the preparation of the leaves is tedious. In the leaf also are minute particles of yellow wax, which are not separated in the boiling process, nor are they noticed until the paper passes between the calenders, when they are pressed out into yellow spots. Diss grass, a taller grass than esparto, and not so strong, has also been used, and is at present imported in some quantity; but as both this and palmetto require more caustic in the boiling than esparto, and do not yield so much fibre, they can only compete with that substance when it is at an exceptionally high price. The fibrous bark of the baobab tree (*Adansonia digitata*), an enormous tree growing in immense quantities on the west coast of Africa, yields a very strong hard fibre, which, if it could be secured at a sufficiently low cost, would be an excellent material for paper-making, the paper produced from it being very tough and strong, almost as strong as parchment. New Zealand flax and the waste from the manufacture of this substance are excellent materials, but at present they are much too costly to compete with esparto. Many other fibres have been tried, such as bamboo, plantain, cocoa-nut fibre, all of which are capable of being converted into paper; this, indeed, may be said of the fibrous portion of any plant, and considering the immense portions of the earth's surface which are covered with a vegetable growth of such luxuriance as to be almost impenetrable—some of them loaded by dense forests of trees so thickly overgrown and tall as to shut out the light of heaven, and others covered by rolling prairie and savannah, the crops of which, year after year, are never gathered, but are literal "waste products," except as forming food for the herds of wild animals which roam over them at will—we cannot but be convinced that we are but at the threshold of the use of vegetable fibres available for the manufacture of paper. No doubt the enormous demand—increasing in almost geometrical progression year after year, as the spread of education and facilities of intercourse increase—for this most civilising of manufactures will be met by a proportionate increase in the quantity and variety of materials. We look with interest at the various experiments which are now being carried on, but with no fear of a favourable result. The field is wide, and the labourers are many and energetic; and one by one the difficulties are cleared away, and new sources of commercial enterprise are opened up, new materials being added to the already great variety of those from which are made the medium that enables us to diffuse our knowledge amongst each other, and to hand down that knowledge to our successors to all future time.

THE BAOBAB TREE (ADANSONIA DIGITATA).

SHIP-BUILDING.—II.

BY W. H. WHITE,

Fellow of the Royal School of Naval Architecture, and Member of the Institution of Naval Architects.

ELEMENTARY REMARKS ON THE STRENGTH AND STRAINS OF SHIPS.

Before setting out on the course indicated in the last paper, it may be well to draw attention to a few general principles in connection with the construction of ships to which reference will be made hereafter. The great aim of the ship-builder should obviously be to construct his ships in such a manner as to obtain the greatest possible strength with the least possible weight of material, and at the smallest cost. For instance, a merchant ship of certain form and dimensions is to be built. When laden to a certain draught of water, the weight of water she displaces is a certain fixed quantity which can be calculated; this equals the total weight of the ship herself and all the cargo she can carry at that draught. Hence, any reduction in the weight of the ship means an addition to her cargo-carrying power, *i.e.*, to the chance of her commercial success; and it also probably means a saving in the cost of construction. Now to fulfil this fundamental condition, this axiom of right construction, the builder must distribute the material in the ship so that it may be situated in the best possible manner for giving strength to the structure. To take a very simple illustration, we will suppose a beam to be required to support a known weight in a certain position. Then by calculation, a skilled designer could estimate what part of the beam would have to resist the greatest strain tending to bend it, and he would fashion the beam so that at each part the amount of the material should be proportioned to the strain it had to bear. What can be done with comparative exactitude in this simple case cannot, of course, be done in the case of a complicated structure such as a ship, subjected as it is to straining forces of unknown magnitude, and of rapidly varying character; and in which, moreover, the designer has to study how best to accommodate the passengers or crew, carry the cargo and stores, make provision for safety, and meet many other demands that sadly interfere with the arrangements which might be made on purely theoretical grounds. Still there are many opportunities which may be made use of in order to make practice and theory agree more closely than they would otherwise do, and to these allusion will be made hereafter.

Another principle of construction, which from its very simplicity is sometimes overlooked, is expressed by the well-worn saying, "Nothing is stronger than its weakest part." This is very nearly related to the condition just laid down, that the best distribution of material is that which proportions its amount at every place to the strain which that part of the structure has to bear; but in a ship, composed as it is of very many pieces, the combination of these pieces is of no less importance than the provision of sufficient dimensions—or "scantling," to use the ship-builder's term—in the various parts. For example, the outside planking of a wood ship may be very thick; but if, through want of proper care, a very large number of "butts"—that is, of the endings of planks adjacent to one another in the longitudinal sense—occur at any particular transverse section of the ship, then there will be found a weakened part which will be likely to give way first. Or taking another illustration: in an iron ship, where the transverse water-tight partitions, or "bulkheads," are placed, the outside plating is often weakened greatly by numerous and closely-spaced holes which receive the rivets securing the bulkheads, and unless precautions are taken, there is a danger of fracture taking place through this line of holes—the "weakest place" which measures the strength of the ship. It is well known that in several instances iron ships have actually broken in two in the manner indicated, and persons unacquainted with the real cause have thought the accident due to something inherent to iron ships, whereas it was the result of neglecting the simplest principle of construction. In some cases, moreover, where weaknesses have been observed in ships, material added for the purpose of strengthening them has been worse than useless, because of the fact that the additions have left the original weakened section unstrengthened. *Uniformity* of strength can only be obtained by careful combinations of the various parts of a ship, even supposing that their *scantlings* have been properly proportioned; but unless such uniformity is aimed at, and discontinuity, or sudden changes of strength in adjacent parts avoided, satisfactory results cannot be obtained. Endeavouring to arrive at the nearest approach to uniformity, the ship-builder will be amply repaid, and will produce a lighter, stronger, and cheaper vessel.

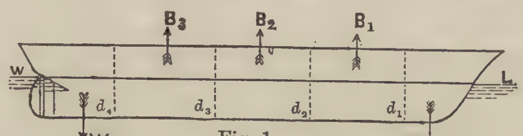


Fig. 1.

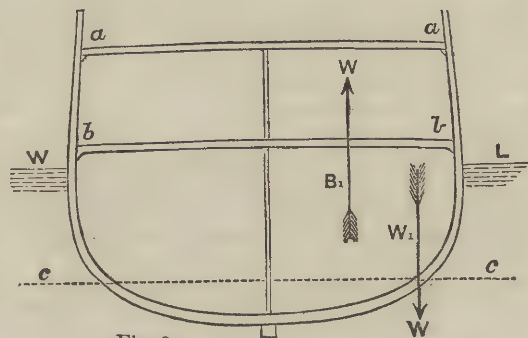


Fig. 2.

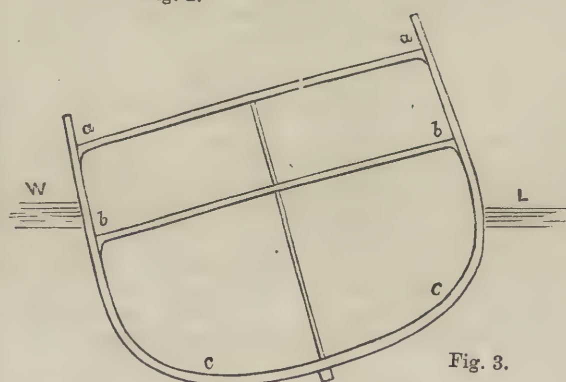


Fig. 3.

The foregoing remarks, with but slight changes of illustration, are as applicable to many of the works of civil engineers as they are to those of ship-builders; but in applying the principles to practice ship-builders have by far the more difficult task to perform, for they have to deal with straining forces of which it is practically impossible to determine the magnitude, whereas civil engineers can in most cases approximate to the maximum strains to which their constructions are likely to be subjected. Besides this, the civil engineer has mainly to deal with *fixed* bridges, girders, etc., while the ship-builder has to construct vessels carrying their own propelling apparatus, capable of moving at high velocities, and strong enough to withstand the shocks of waves, as well as the heaving, rolling, and pitching motions impressed upon them. To estimate with accuracy the straining forces acting upon a ship at sea is, in the present state of mathematical science, an impossibility; and on this account ship-builders have to depend very greatly upon experience and precedent in determining the requisite strength for ships. Knowing that some vessels, built on certain principles, have proved sufficiently strong, the designer has to provide a proportionate amount of strength in the vessel to be built, or at least not to depart so far from his model at one step as to possibly pass the limits of safety. But while this is true of the provision of strength in the ship as a whole, it is no less true that in making the detailed arrangements for giving the desired strength there is a large field for originality and improvement, and it is in this direction mainly that changes have been made of late years.

In speaking of the strength and strains of ships it is most common to compare them with girders. The comparison is a

very old one, having been made by the great French writer, Bouguer more than a century ago, and repeated by nearly every succeeding writer of note in dealing with the question. Since the construction of the Britannia and Conway tubular bridges, however, the comparison between ships and girders, in so far as their *strengths* are concerned, has become much more exact, and this result is mainly due, we believe, to Sir W. Fairbairn, who took a very prominent part in the experimental researches upon which the construction of those bridges was based. By this means we are enabled to gain a far more definite idea of the comparative strengths of ships than could otherwise have been obtained, and under known, or rather *assumed*, conditions the ship-builder can foretell with moderate certainty whether the vessel will be capable of resisting the strains brought upon her. For example, if she is supposed to rest upon the ground in such a manner as to be supported only either at the extremities or at the middle, then she becomes practically a *fixed* girder, and the strains can be calculated in the same manner as those for a bridge are determined, as can also the powers of resistance of the ship. Sir W. Fairbairn, and others with him, think that this would be a fair test for the ultimate strength of all ships; but, on the other hand, it is urged that there is so small a probability of a ship ever taking the ground in either of these extreme positions of support that it is unnecessary to provide so great strength as would be required to endure the strains resulting therefrom. It is but fair to add that instances are on record of ships having been placed in the circumstances assumed, but they are so few and far between as to have little influence on practical construction. Builders naturally regard ships as intended primarily either to remain afloat or to take the ground in a different fashion from that described above, and there is doubtless much to be said in favour of their view. Its weakness consists, however, in the fact that it is impossible to estimate the greatest strains brought upon a ship when afloat among waves with the same accuracy as when she is aground; so that, as was said before, the only means of judging of the sufficiency of her strength to resist the strains to which she may be subjected when afloat is by comparison with other vessels. Attempts have been made, it is true, with some success, to approximate to more definite conclusions, but the furthest result hitherto reached is far from satisfactory. No one has yet succeeded in expressing (by figures) quantitatively the straining effects produced upon the hull of a ship by the violent motions to which she is subjected when at sea; nor does it seem probable that this extremely difficult problem will soon be solved.

The only case which can at present be made the subject of comparatively accurate calculation, is that of a ship floating at rest in still water. By well-known methods it is possible to estimate the upward pressure of the water upon any portion of the vessel, seeing that the pressure exactly equals the weight of the water displaced by that portion; and it is also comparatively easy to find the weight of any part of the ship, together with its contents. A simple illustration will help us here. In Fig. 1 is represented a ship floating in water, the surface of which is shown by the line W L. Let us suppose four imaginary divisions (marked d_1, d_2, d_3, d_4, and dotted) to be made in the ship, which may be thus conceived to consist of five distinct parts. At the bow, where the immersed part of the ship is very fine or sharp, we will suppose the weight of the portion of the ship cut off by the division d_1 to exceed the buoyancy of that portion by a force whose amount is W_1, and which is represented in direction and position by an arrow. Similarly at the aftermost portion, we will assume an excess of weight to exist, and to be represented by W_2. For the remaining three parts, situated near the middle of the ship where the under-water form is fuller, we will suppose the buoyancy of the respective parts to be in excess of their weights, and represent these excesses, acting upwards, by the letters B_1, B_2, B_3, as to amount, and by the arrows as to position. It will be obvious, therefore, since the total weight of the ship and lading equals the total buoyancy (or weight of water displaced), that the sum of the three upward pressures, B_1, B_2, B_3, must exactly equal the sum of the two downward pressures W_1 and W_2; and it will also be clear that from the positions at which these pressures are supposed to act, there will result a tendency to make the ends of the vessel droop relatively to the middle. Such a change of form is termed in technical language "hogging," and the opposite change, when the middle of a ship droops relatively to the ends, is termed "sagging." The former is the more common change, and is especially observable in old wood ships; "sagging," although less common, may sometimes be seen in long steamers with very heavy weights of machinery, etc., placed near the middle, and causing a considerable excess of weight over buoyancy at that part.

From this simple illustration it will appear that the straining forces brought upon a ship when floating in still water depend largely upon the manner in which the weights she carries are placed, and also upon the form of the vessel under water. When these particulars, and the details of the weights of the hull of the ship, are known, the straining forces can be calculated with a fair amount of accuracy, and the relation which they bear to the ultimate strength of the vessel, considered as a girder acted upon by known vertical forces, can be determined.

Different classes of vessels are, as might be expected, subjected to very different kinds of straining forces, when floating in still water; and the same ship may, at various times, have very various strains brought upon her hull, by changes in the stowage of the weights carried by her. Turning once more to our simple illustration in Fig. 1, we might suppose that instead of having an excess of buoyancy throughout all the middle part of the vessel, some very concentrated weight—such as a cargo of railway iron—is placed there, and the ends left almost free from weight. Then we might have downward pressures amidships, and upward pressures at the ends, tending to make the ship "sag." Or, contemporaneously with the excess of weight we have imagined amidships, there might also be excesses of weight at the bow and stern, so that we should then have, say, the upward pressure B_2 in Fig. 1 turned into a downward pressure; and its amount added to W_1 and W_2, balanced by the upward pressures, B_1 and B_3. This is a more complicated case than the preceding one, but it is far more likely to be met with in actual ships, where there is almost always an excess of weight over buoyancy, at both the bow and stern, when floating in still water.

It will appear, therefore, that even when at rest a ship may at different times be strained in very different ways, according to her stowage, particularly if she be a merchant ship, carrying a very heavy cargo, and that consequently great care ought to be taken in stowing the cargo. Sometimes she may tend to hog throughout the length (the case represented in Fig. 1); at others there may be a tendency to sag amidships as well as to bend the ends down, thus tending to make the ship assume a sinuous form, under the conditions of stowage last stated; at others, but only very rarely in ships floating in still water, the vessel may tend to sag throughout her length. Hence it will appear that a ship's structure must be capable of resisting strains tending to bend it either upwards or downwards, and the various longitudinal pieces must be capable of bearing tensile forces, tending to tear them asunder, or compressive forces tending to crush them. This is a fact important to note, the importance of which will be more fully appreciated when we glance at a ship's condition in a sea-way.

From the general sketch of the causes of hogging and sagging given above, it must not be imagined that sagging strains are brought upon every part of a ship where there is an excess of weight, and the caution is given because the contrary is often assumed to be true. Without entering into the question at length, which is out of our power here, we would observe that in all such cases as that represented by Fig. 1, or the modifications thereof that have been imagined to be made, it is necessary, in order to calculate the bending force at any cross section of the vessel, to take into account all the vertical forces acting on *one side* of that section, either towards the bow or towards the stern. Hence it may happen that even with a considerable excess of weight amidships, if there is also a large excess of weight at the bow or stern, there may be no sagging strains, because the effect of the one is neutralised by that of the other. So far as has been yet ascertained, the only cases where sagging strains actually occur, are those in which the excesses of weight amidships are *very considerable*, and their effects are not counterbalanced by the effects of the downward pressures at the bow or stern. The popular idea that sagging *always* accompanies excesses of weight near the middle of ships, is based upon the fact, that such concentrations of heavy weight bring severe *local* strains upon the subjacent parts of the ship, and alterations of form have in some cases occurred in consequence;

but this is a very different thing from that properly termed "sagging."

For example, if a beam resting near either end upon a wall, beyond which the ends projected, were loaded with heavy weights, W_1 and W_2, as shown in Fig. 4, and also carried near the middle a weight W_3, it would exactly illustrate the case of the ship that *might* sag amidships; but it is a matter of common observation that such a beam might, even with the load W_3, continue to be convex upwards or hog throughout its length, supposing it to bend under the action of its load. It might also happen that the weight W_3, if very heavy, would arch the beam downwards, while the action of the weights W_1 and W_2 might make the ends droop; the final effect being to give the beam a *sinuous* form, such as we supposed a ship might be made to assume. In both cases, however, the weight W_3, being concentrated, would tend to make the beam *bulge*

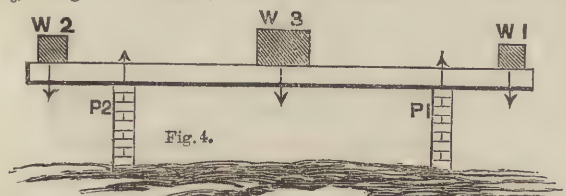


Fig. 4.

down immediately below it, and this tendency corresponds to the local strain referred to above as being sometimes confounded with sagging. We might obviously, by very simple means, so strengthen the beam near the place where W_3 rests, as to prevent any bulging, and yet not interfere with the general character of the curvature which the beam assumes; and in the same manner, by various strengthening pieces, the ship-builder provides the necessary local strength which experience shows to be required under concentrated weights. This distinction between *local* strength and the strength of a ship *as a whole* must always be carefully remembered. It is in the latter particular only that the comparison is usually made between the resistance to straining forces offered by ships and girders.

Respecting this comparison, a few words of explanation will be needed, and these will probably be rendered clearer by the outline transverse section of a ship, floating upright in still water, shown in Fig. 2. When a beam or girder is subjected to bending strains, the greatest intensity of the straining force at any cross section is experienced by the uppermost and lowermost parts of the beam, as is shown by the fact, that if rupture takes place, the beam begins to fail at either its upper or lower surface. Theory teaches, too, that near the middle of the depth of the beam (or, speaking more exactly, at the centres of gravity of its cross sections) there is a part—known as the "neutral surface"—which is not subjected to tensile or compressive strain; and that as the distance of any other part from this "neutral surface" increases, so also does the strain it has to bear become increased. Consequently, in designing beams, it is usual to throw as much of the material as possible into the "flanges" which are most distant from the neutral surface, and are therefore most strained; the web in such cases is but little strained, and is of minor importance—in fact, need only be made stiff enough to efficiently connect the flanges. In "lattice-girders" the principle receives its fullest development, the web being formed by the lattice-bars, while the flanges are made up of strong combinations of plates and angle-irons.*

Keeping these facts in view, let us turn to the cross-section of the ship shown in Fig. 2, which may be considered as representing on an enlarged scale the cross-section at d_2 of the vessel illustrated by Fig. 1. The conjoint action of the forces W_1 and B_1 obviously tends to break off the part of the vessel before d_2 from that abaft it, and as the result a tensile, or stretching, strain is brought upon the upper part of the ship, while a compressive strain has to be resisted by the lower part. Near the middle of the depth there will be a neutral surface subjected to neither tensile nor compressive strain, and the parts adjacent to it will have but little strain brought upon them. It will be clear, moreover, that only those portions of the vessel's structure which run longitudinally can be of assistance in preventing her from breaking across the deck or bottom and down the sides. For instance, the beams under the decks, being placed transversely, can lend no more help to the longitudinal deck-planks, than can the transverse pieces of the roadway of a bridge help the longitudinal girders which stretch from pier to pier. Hence we have to look upon the decks (without the beams), the planking or plating of the sides and bottom, and the various internal strengthenings running through the length of the vessel, as forming the component parts of a hollow girder, giving longitudinal strength to the structure. The more important flanges of this girder are formed by the upper deck (marked *a a* in Fig. 2), and the bottom up to the height of the bilges (say up to the line *c c* in the diagram). The webs joining these flanges are less important, from this point of view, and they are formed by the skin and other longitudinal pieces; while the intermediate deck, *b b*, may be regarded as a subordinate flange. With these assumptions it is not a difficult matter to estimate approximately the longitudinal strength of the structure at the section in question, and to compare it with the calculated straining force at that section when the ship floats at rest in still water.

The still-water strains to which ships are liable do not, however, compare in magnitude with those experienced by them when at sea. No argument is needed to support this statement, but an illustration or two of its truth may not be out of place. When floating amongst waves a ship may be supported in such a manner as to greatly exaggerate the unequal distribution of the weight and buoyancy existing in still water at various portions of her length. For example, if the vessel illustrated by Fig. 1 chanced to ride upon a single wave, the crest of which was for an instant situated near the middle of her length, the result would be a very large increase in the excesses of buoyancy (B_1, B_2, B_3) amidships, and in the excesses of weight (W_1, W_2) forward and aft, this change producing, of course, much greater hogging strains. On the other hand, if she floated astride a wave-hollow, with her bow and stern buried deeply in the wave-slopes, and the middle portion partially denuded, an entire change might be wrought from the condition in still water, and severe sagging strains might be brought upon the structure. Many other changes might be imagined, and would undoubtedly occur at some time or another; but the preceding cases will suffice to show how much more unequal may be the distribution of the weight and buoyancy in a ship amongst waves than it is in still water, and how much greater must be the strains to be resisted.

Adding to this consideration the fact of the *rapidity of the changes of strains* under these conditions—a very few seconds sufficing to entirely reverse their character, turning great hogging strains into great sagging strains, and *vice versa*—we see how necessary it becomes to provide strength to resist both; and when it is recollected that additional intensity is imparted by the heaving and pitching motions which the ship is compelled to perform, we obtain a still better conception of the all-importance of these strains at sea, as compared with still-water strains. Nor must it be overlooked that contemporaneously with the violent changes indicated above, the vessel must often be rolling heavily from side to side, so that positions must frequently be reached in which the conditions illustrated by Fig. 3 will hold, and the resisting power of the ship to longitudinal bending strains will be similar to that of a hollow girder set angle-wise. Portions of the structure which in the upright position had little or no strain to bear, now become severely strained; and conversely, those which were of most importance in the upright position sink into a subordinate place.

Stress is laid upon this point because there has been a tendency to restrict the consideration of a ship as a girder to the upright position, and to distribute the material in accordance with that idea. For example, many persons have strongly urged reductions in the thickness of plating near the middle of the depth in iron ships, because in the upright position this would be near the neutral surface.* To carry such reductions far would, however, obviously be improper, for the reasons just assigned. At the same time it should be remembered that the upright position is that in or near which the vessel is most frequently situated, so that it is right to regulate the distri-

* Take, for example, the simple case of a bent beam, which was originally straight. In order that it may become curved, it is obvious that the layers of material lying near the convex surface must have been stretched beyond their natural length, while those lying near the concave surface must have been compressed within their natural length; so that between the two surfaces there must occur a layer—the neutral surface—which is neither stretched nor compressed.

bution of the material in the cross-section more by the consideration of the relative importance of the various parts under that condition, than by any other reasoning. In this view the majority of ship-builders are now agreed, and as a result we find far more attention paid to the strengthening of the upper parts of ships, particularly of the upper decks.

In considering a ship as a girder, it must be remembered, too, that its breadth gradually decreases from the centre towards each end, and that consequently the strength of the cross-section diminishes towards the extremities. Many ship-builders consider that in spite of this decrease in breadth and strength there is still a larger reserve of strength in proportion to the strains brought upon the sections near the extremities than there need be; and in consequence they have urged the propriety of a larger reduction in the thicknesses and scantlings of the parts near the bow and stern than is now common. Some reduction, it should be stated, is always made, but the question of amount has been one that has occasioned much debate, and it is still unsettled. The popular view is that the diminution in strain commences from some section near the broadest and fullest part—the "midship section," as it is called—and that it progresses gradually towards the extremities. This view, in so far as still-water strains are concerned, has, however, been proved to be inaccurate by investigations made on actual ships, in some of which it is found that the section of maximum strain is at a considerable distance before or abaft the midship section. But while this is true of still-water strains, it must be borne in mind that there are more important strains to be taken into account—those experienced at sea; and there is good reason to believe that in all classes of ships under the latter condition the maximum bending strains do occur at or near the midship section, the amount of strain at other sections diminishing towards the ends of the vessel. On the whole, therefore, the popular view may be regarded as a correct one so far as its influence on the disposition of the material is concerned; but experience is, as yet, the best guide we have in making reductions in scantlings, and theoretical considerations are justly outweighed in this particular by practical requirements. Still every sound effort to make practice and theory approximate more closely must be advantageous, seeing that it helps on towards the ideal of structural perfection—the proportioning of the material to the strains it has to endure.

THE LATHE.—II.

By Henry Northcott.

LATHE WITH FLY-WHEEL ABOVE—LATHE WITH FLY-WHEEL BELOW—MODERN HAND-TURNER'S LATHE.

Lathes whose motion is derived from an independent fly-wheel are convenient when work has to be accomplished that requires rather more power than the workman himself can exert, and yet not enough to give employment to a steam-engine. Many such lathes are still to be seen in country towns, chiefly in the workshops of blacksmiths and wheelwrights. But where so much power is not required, it is rather too expensive a plan to employ an assistant only in order to obtain continuous rotation in one direction, and consequently other methods have been devised to enable the turner himself to produce this. One of these plans is illustrated at Fig. 5, and consists, as will be seen, in placing, as it were, the independent fly-wheel over the operator's head, retaining the winch-handle, but enabling the turner himself to work it, by bringing down a rope with a handle at the end to form a kind of bell-rope. This rope is brought down in such a position as to be within convenient reach of the turner when he is standing at his work. It is obvious that by pulling this rope—the winch being in favourable position, shown in the drawing—the wheel and its shaft would be caused to rotate, and if the tension were removed so soon as the centre of the winch-pin got into the straight line joining the hand and the wheel-axis, the momentum of the pulley, purposely made heavy, would carry it round the centres, and bring the winch-pin again in a position where the workman could pull with advantage. But whenever the wheel overhead stopped in such position as to leave the centre of the winch-pin in a straight line passing through the workman's hand and the centre of the wheel's axle—a position known to mechanics as being "on the centres"—the wheel could not be again started by any amount of pulling, but it would be necessary to move it over the centres by some force otherwise applied. The wheel being overhead, too, and out of easy reach, it is clear that liability to such stoppages "on the centres" would be most annoying. Fortunately, however, they are easily obviated by placing a small weight on the pulley near the rim, and on that part of the pulley that would be nearest the floor at the time the winch-pin would be in the most favourable position for being started from. The action of the weight is simply to rather more than counterbalance the weight of the winch-pin and bell-rope, and to overcome the friction of the axle in its journals. This expedient enables the workman to drive his work always in one direction, and either towards

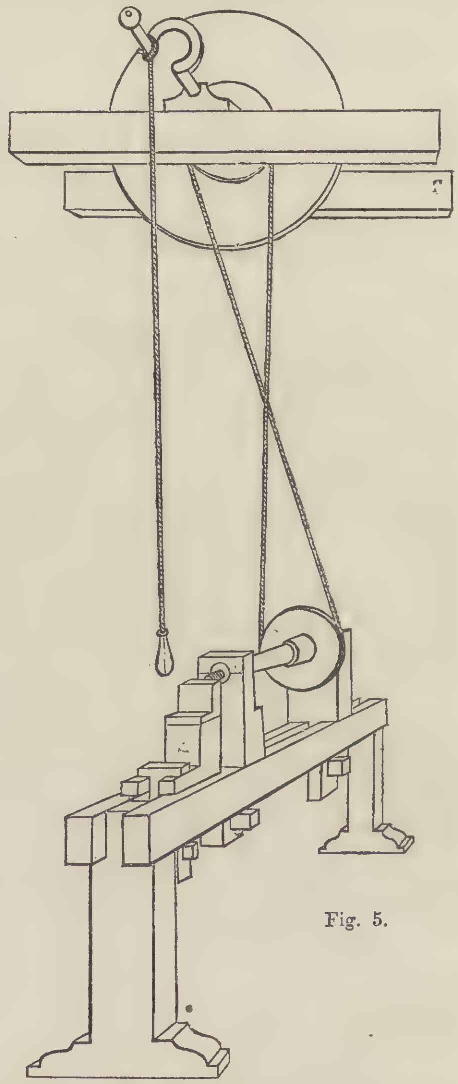


Fig. 5.

him or from him; but one of his hands being employed in pulling this rope, he has only one hand to guide and steady the turning tool. Now this also was a very great inconvenience, since for fine work the tool requires to be guided with very great care to prevent injury to the work, and for large work it is necessary to hold the tool firmly on the rest to prevent its being violently jerked out of the workman's hand.

One very obvious plan of relieving the hand would be that of lengthening the pulling-rope to bring it down to the workman's foot, and there furnishing it with a kind of stirrup or pedal. This would be quite as easy to drive as the last, and it is plain the foot is as competent as the hand to periodically draw down the cord, besides being much more powerful.

Another plan is that of removing the pulley and its axle from

their place overhead, and placing them underneath the lathe bearers, with the winch-handle projecting beyond the left-hand end of the lathe-supports. Then by hanging a long lever on to the winch-handle to serve as a treadle, the axle and its pulley could be rotated as before with the foot, thus leaving the hand free. The lathe-spindle in this arrangement, as in the last, is driven from the large pulley by a cord, which may be either crossed or not, as is most convenient under the circumstances of driving. The lathe illustrated at Fig. 6 shows this last arrangement somewhat modified to render it more conveniently actuated.

For light lathes, where steam or other external motive power cannot be obtained, the crank and fly-wheel are almost always used to obtain the necessary motion, and in substantially the manner shown in the last figure. By this mechanism the rotation is continuous; it is as easy to drive in one direction as another; the speed and power may be easily regulated within certain limits by merely treading with the foot faster or slower, harder or softer; and both hands of the turner are free to be used in the more delicate operation of cutting the work into shape. This division of labour is also more in consonance with our ideas of the fitness of things, for although in Eastern countries the *foot* is used to guide and steady the tool whilst the *hand* causes the work to rotate, it may nevertheless be considered that the guiding power is more difficult of attainment than the moving power, and that the hand is the better adapted for the former, and the foot for the latter.

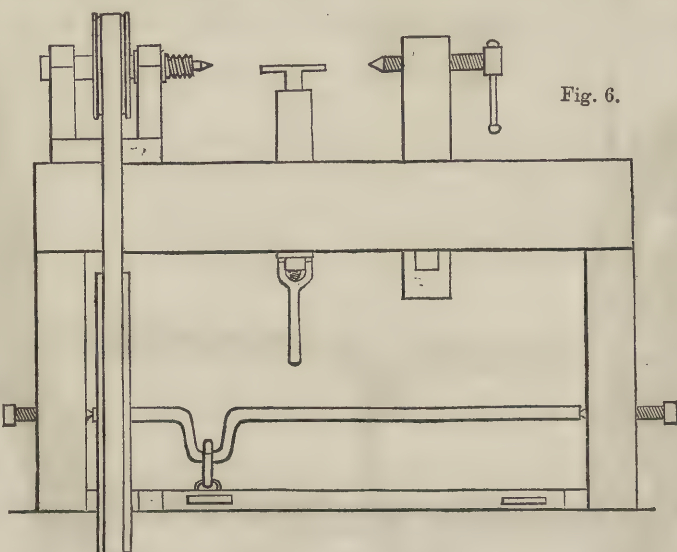


Fig. 6.

In practice also the crank and treadle leave very little to be desired. No doubt, to the beginner, who generally persists in treading at the wrong time, or when the crank is in the wrong position, the difficulty of regularly treading appears to be very great, and consequently an even motion of his work impossible to attain. The greatest difficulty, however, is to prevent the body swaying a little with the motion of the foot, and the tool from following the movement of the body. Many turners never learn to tread with the leg only. But, as a rule, all these difficulties vanish with practice, and the tools can be held as steadily and guided as surely when treading as when not treading. Nevertheless, it is usual amongst certain classes of turners to employ a back-rest, or support for the back. This rest consists simply of a long piece of board placed flatwise from end to end of the lathe at the turner's back, to receive the outward pressure of the back, and prevent its motion whilst the treadle is being forced downwards. There is no doubt this back-rest is a support and an assistance to the turner when turning heavy work, as at such times the force required to press the treadle downwards is considerable; but generally its aid can be dispensed with, without inconvenience. So also for light work, the tendency to unsteadiness can be lessened by reducing the throw of the crank and the lift of the treadle; and an arrangement allowing the distance of the crank-pin from the centre of the shaft to be adjusted as required is more often applied, and more useful, than a back-rest, although the majority of turners use neither expedient.

I cannot pretend to say that the course I have described has been the one precisely followed by the march of improvement; and numberless modifications have also been made in the lathe, to which the limits of my space prevent reference. But the various steps of improvement here indicated are such as appear with most probability to have been taken, and it will be seen that the application of the crank and fly-wheel to the lathe—certainly one of the most valuable additions ever made to it—may have been led up to very gradually, and so imperceptibly, that its use may not have appeared a very great improvement upon existing methods of deriving the necessary motion.

Fig. 7 shows the hand-turner's lathe in its modern form. With the exception of the treadle-board *a*, and tool-shelf *b*, it is constructed entirely of metal; the bed or bearers being cast-iron, accurately planed upon its upper face and inside edges, so that the poppets or headstocks may, in the first place, be set accurately in line with each other, and be moved along the bed without interfering with this accuracy. The poppet carrying the screw and the tool-rest holder are easily fixed in position by a turn of the screws underneath, and the rest-holder may be fixed at any convenient distance from the work, and at any convenient angle; also the rest, or T as it is frequently termed, may be raised or lowered in the socket of the holder so as to allow of the cutting edge of the tool being brought into suitable position for operating upon the materials. The crank-shaft should be turned throughout its length, and be accurately mounted between the two supporting centres as shown. These centres are made of steel and hardened at the points; the ends of the crank-shaft are also hardened, so that the two bearing surfaces being hardened, and moreover very smoothly turned, the friction is almost nothing, and the wear of the points very little. They, of course, require to be occasionally oiled to prevent abrasion, and it is inadvisable to screw them up very tight, but preferable to give the shaft a little "play" rather than otherwise. The treadle-board and levers are also supported in much the same way between two centre-points with a screw-thread cut upon them, and lock-nuts for preventing any motion of the screws from the friction; and the link joining the treadle to the crank is formed with a pin-joint at the bottom, and a flat hook at the top where it rests upon the crank. This hook form of connection is adopted in order that, should the operator inadvertently place his foot underneath the treadle-board, it may not be crushed by the momentum of the fly-wheel, but that as the board reaches the obstruction it may unhook itself from the crank, whilst allowing the crank-shaft to rotate unimpeded and alone. The flat form is also given to the top part of the connecting-rod hook, for the object of obtaining larger bearing surface for it upon the crank, and of reducing the wear. This arrangement of the treadle and crank-shaft is very simple, and is probably oftener used than any other; but in many lathes, with a view of reducing the friction to a minimum, the crank-shaft and fly-wheel are mounted upon friction rollers instead of between points, and a flat chain is used to connect the crank and treadle, instead of a rigid link. The advantages possessed by these alternate arrangements are not very considerable, nor do they require to be specially illustrated, but lathes embodying these expedients will be described hereafter. The fly-wheel of this lathe serves as the main driving-pulley, being furnished on its edges with a series of deep V-grooves, for carrying a round driving-gut as shown. There are three sets of grooves on the face of this wheel, and in order that any set may be brought immediately underneath the corresponding grooves in the lathe-pulley, an arrangement is made for shifting the fly-wheel upon the shaft, and fastening it in either of the required positions. These various sets of grooves are very convenient, being necessary for obtaining greater variation in the speed of the work than can be got by treading faster or slower, or by the single set of grooves. It must be observed that each set of grooves consists of

four; in each set the diameters of the grooves decrease towards the right hand in a regular manner, whilst the diameters of the corresponding grooves cut in the lathe-pulley increase in the same manner towards the right hand. The proportions of these various diameters must be such that the same gut-band shall be equally tight when running upon any corresponding pair of grooves. Supposing the foot is moved up and down one hundred times per minute, in which case the crank-shaft and fly-wheel will rotate one hundred times also per minute, and we are turning some small work requiring the fastest speed we can obtain; then the gut-band must be placed upon the extreme left-hand or largest groove of the driving-wheel, and upon the extreme left-hand or smallest groove of the lathe-pulley. With relation to the grooves of the lathe-spindle pulley, that the gut belonging to that set of grooves runs equally well upon any corresponding pair. It is a usual practice, instead of having three separate guts, to have one gut fitting the smallest set of grooves, and to have two short lengthening pieces of different lengths, the shortest of which, being hooked on to the main gut, makes it long enough for the next largest set of grooves, and the longest lengthening piece being hooked on instead of the other, the gut becomes long enough to run upon the largest set of grooves.

The spindle of this lathe is made of steel; it has one bearing only, in the front end of the headstock, and its left-hand end is supported by a centre-point formed upon the end of a steel screw passing through the headstock, and having a lock-nut to

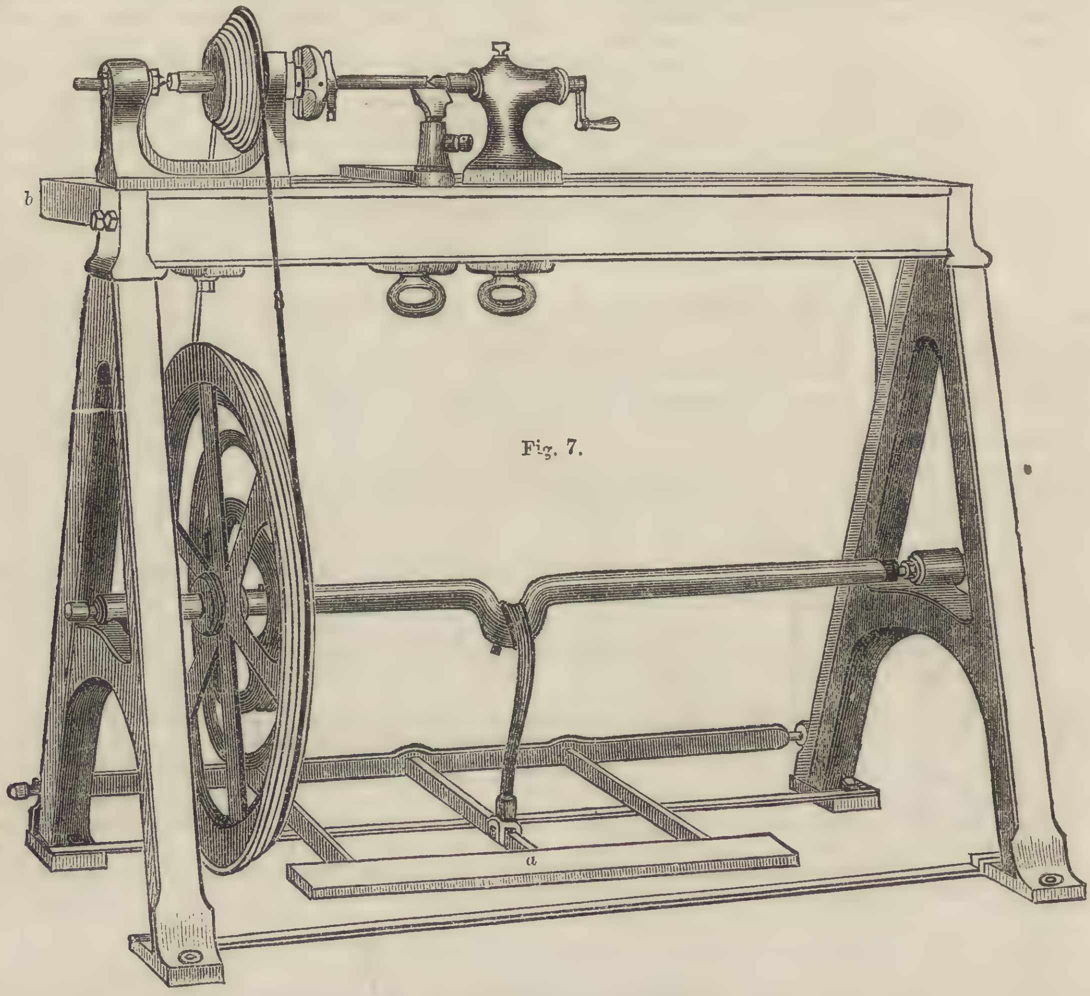


Fig. 7.

the band in this position, and with a 30-inch driving-wheel and a 2-inch groove on the lathe-pulley, the speed of the lathe-spindle and work would be about 1,500 rotations per minute, which is a very useful speed. Should this speed be rather too high, the gut is shifted on to the next pair of grooves, or to the third or fourth pair if necessary. Beyond this no further reduction can be made by this set of grooves; but by using a shorter gut-band, and shifting the driving-wheel upon the shaft, so as to bring the next set of grooves underneath the corresponding grooves of the lathe-pulley, we have four more variations in speed. By using a still shorter gut, and bringing the smallest set of grooves on the driving-wheel under the lathe-spindle, the speed is still further reduced, and we get four more variations in the speed of the work.

In using these three sets of grooves, it is obvious that three separate lengths of driving gut are required, one length for each set; but the four grooves of each set are so proportioned in prevent movement. The front bearing is in the form of a frustrum of a cone, taking its bearing not in the cast iron of the headstock or poppet, but in an accurately made and hardened socket, carefully fitted into the metal of the poppet, a small hole being drilled down through the metal of the headstock and the hard socket forming the bearing, to allow of a few drops of oil being occasionally applied to the rubbing surfaces. In this form of bearing with a back-centre support, it is essential that the bearing surfaces should be very accurately formed, carefully hardened, and ground to a good bearing by the use of a little emery and oil after the hardening process, and with all the working parts in proper place. It is also necessary that the screw forming the back support should be cut carefully in the lathe, so as to be as true as possible, as if the thread be "untrue" or "drunken" the centre line of the lathe-spindle will be displaced each time the screw is turned round for the purpose of taking up the wear. And even when every precaution is taken, this

disarrangement of the centre line occurs through the weight of the spindle and its pulley, and the downward pull of the gut, causing an unequal wear of the centre-point. For this and for other reasons, another solid bearing is frequently provided for the lathe-spindle instead of the centre-point; but perhaps for simple hand-tool lathes the centre-point support is as good as any. The tool-rest and holder will be understood without further description, but the left-hand poppet is of a somewhat puzzling construction, at any rate to the ordinary reader. In order, therefore, to make the arrangement of this and other parts as plain as possible, I have given at Fig. 8 a sectional elevation of the entire lathe, which shows the construction of almost every important part of it. From this sectional view it will be seen that, instead of the right-hand centre-point being formed upon cylinder, and the latter is drawn into the hole of the poppet-head. By moving the hand-wheel and screwed spindle in the contrary direction, the cylinder is forced outwards, and the centre-point forced into the end of the work to which it has to act as a support. In using the lathe, the practice is first to loose the holding-down screw of the poppet, pull the whole poppet along the bed until the centre-point is against the work, then fasten down the poppet by tightening the nut of the holding-down screw so as to prevent the poppet moving, and force the centre-point into the wood or other material, by means of the hand-wheel and the forcing screw of the poppet.

In using the lathe, the steel centre-point upon which the work rotates will gradually wear blunt, and this will be especially the case if much metal be turned in the lathe, and the bearing

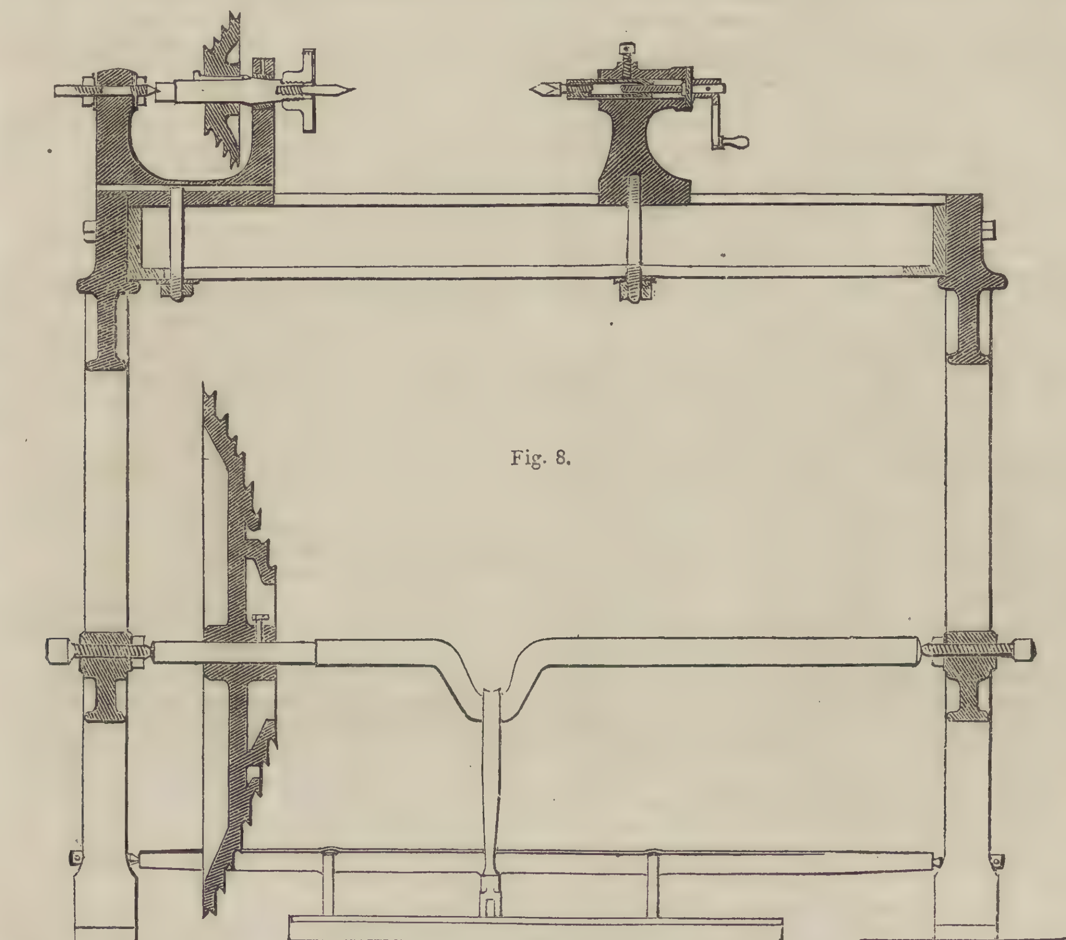


Fig. 8.

the end of a screwed cylinder, which requires turning round to advance it, and to force the point into the wood to be turned, the centre-point is formed of a small independent piece of steel, hardened and formed with a screwed shank, by which it is screwed into, and caused to form a part of, the plain cylinder of the poppet-head. This plain cylinder is accurately turned, and the poppet-head is as accurately bored out to receive it; the cylinder having to slide freely, but without shaking, into the hole of the head. The cylinder is bored throughout its length, and at its inner extremity it is furnished with an internal screw-thread or nut. The poppet-head is also bored throughout, and at its right-hand end a socket, with a small central screwed spindle and hand-wheel, is fitted into the hole, as will be seen in the sectional illustration. The thread or screw cut upon this small central spindle corresponds with the internal screw of the cylinder, so that by means of the hand-wheel, both cylinder and spindle being in place, by turning round the screw in the right direction, the screwed spindle engages with the screw of the surfaces of the point and the work be allowed to get dry. When therefore, from wear or accident, the centre gets too blunt to act properly, it can be unscrewed, removed from the cylinder, and a fresh centre substituted for it. The blunt centre can be annealed or "let down" and turned and hardened afresh, when it may be used again. The projecting end or nose of the lathe-spindle is also furnished with a screw-thread of the same size as that of the cylinder of the other poppet, so that these small steel centres will fit the two holes in common, and a blunt centre is re-turned in position, by simply screwing it into the centre hole of the lathe-spindle, and applying the tools to it as the spindle rotates. The nose of the lathe-spindle is also furnished with an external thread or screw, for the purpose of enabling the various chucks or drivers, used for holding and communicating motion to the work, to be attached to it. The illustration shows the lathe arranged for metal turning, with a centre-point in both spindles, with the work in position between them, and an ordinary driving-plate on the external thread of the spindle-nose.

CHEMISTRY OF THE FINE ARTS.—I.

By Professor CHURCH, Royal Agricultural College, Cirencester.

INTRODUCTION—GRINDING AND WASHING PIGMENTS—ANCIENT AND MODERN PIGMENTS—RELATION OF CHEMISTRY TO ART—WHITE PIGMENTS: WHITE LEAD, ZINC WHITE, WHITING, GYPSUM, BARYTA WHITE.

If the artists of classic and mediæval times possessed a more limited range of pigments than that which is at the disposal of modern painters, it is yet quite certain that they took more interest in the preparation of the materials of their art, and in the judicious employment of them. Our knowledge of ancient pigments is not indeed very accurate or very extensive, but, nevertheless, we may find a good deal of information on this interesting subject in several ancient writers, such as Vitruvius and Pliny the Elder. The actual chemical examination of ancient pigments and paintings has further added to our knowledge, and conclusively proved how largely the treasures of the mineral kingdom were ransacked for the sake of the variety of coloured products which they may be made to yield. Many vegetable and some animal substances were likewise used as pigments by Greek and Roman artists. But there is one thing which is rendered evident in the course of the investigation of this subject, and that is the extraordinary care which ancient painters exercised in the selection and preparation of their colours. They were not satisfied with a red powder simply because it was furnished to them under the name of *rubrica*, but they distinguished numerous kinds of this rubrica, our red ochre, according to the country whence it came, or the subsequent treatment which it received. So, too, with the four kinds of white pigments used by the ancient Greeks; these fetched very different prices, and were esteemed very variously, according to their quality and usefulness. One of the best proofs of the efficacy of a careful and judicious selection and preparation of pigments is to be found in the state of preservation in which some of the ancient pictorial and decorative works of Roman artists exist at the present moment. We might have chosen illustrations of the fact to which we now refer from other countries besides Italy, and from far more ancient examples of the use of pigments; but if many of the coloured materials employed in Pompeii have retained their hues practically unimpaired for nearly 2,000 years, we may rest content with this proof of durability. In speaking, farther on, of the various pigments now in use, we shall describe those employed by the ancient artists where they have stood the test of time.

It will be advisable here to say a few words as to the practice of the painters of the Middle Ages, and of the Renaissance, so far, at least, as their treatment and use of pigments are concerned. On these points we possess a large amount of information, not only that contained in the treatises of Cennini and Vasari, and in many curious manuscript works, but also that drawn from the examination of the pictures and illuminated books which the artists of the Gothic and Renaissance periods have left us. We cannot but be struck by the fineness of texture and the completeness of the purification which the pigments of the periods alluded to exhibit. No directions are more peremptory than those given by Cennini for the thorough grinding and washing of colours, and, in truth, no directions were then or are now more important. "Grind the black," says Cennini, "for half an hour or an hour, or as much as you please; but know that if you were to grind it for a year it would be blacker and better in tint." Again, speaking of vermilion, the same writer says, "If you were to grind it for twenty years it would still be better." But some pigments, such as smalt and malachite, were well known to be injured in hue or weakened in tone by excessive grinding, and so Cennini gives his readers special cautions on this point. Nor were the processes of washing and elutriation invariably employed for the further preparation of pigments; some colours are too soluble and others too impalpable to admit of this treatment. But with many pigments the plan of "washing over" recommended by the old illuminators and limners is still pursued with success. Although the *rationale* of this process was ill understood, it really served to purify the pigments submitted to treatment; it washed away soluble matter and saline impurities which were dissolved in the water used. More than this, however, was accomplished, and not only could coarse and heavy particles (whether of the pigment itself or of foreign matters) be separated from the finer particles, but the finer portions themselves might be separated into several degrees of fineness. A scum or film, too, of light impurities or of very pale-coloured particles, often appeared at the top of the mixture of colour and water, and this could be thrown away. Yet the idea that this scum was a foreign body, and not generally the very pigment itself in a state of most fine division, was certainly erroneous; for the very purest coloured chemical compounds will often yield such a scum when finely ground and then allowed to settle in water. The more transparent the substance, the more likely is this to be the case. Thus, the light which in a crystal of blue vitriol has to pass and repass through its substance, and so becomes deeply and purely blue, when it falls upon the same crystal in fine powder, plunges to but a small depth from the surface, and is chiefly irregularly dispersed as white light but little altered in hue. Exactly the same thing may be noticed in the case of smalt, which is made from a cobalt-blue glass, so deep in colour as to appear black when unground.

The importance of the old method of "washing over" pigments, and its general applicability, will justify us in inserting here an account of the way in which the process was conducted, together with such modifications as have been found useful. The first step is to place the pigment in a large mortar, and add to it sufficient water to moisten it. It is then gently rubbed with the pestle till it has acquired the consistency of thick cream. Colours which have been previously ground in oil or turpentine may require the addition of a little ox-gall or other alkaline substance, in order to render them perfectly miscible with the water, which itself should be as clean as possible, and either rain or distilled water. Some colours, too, which settle very quickly, may need pure gum-water, or pure syrup, instead of plain water, during the earlier operations of "washing over." Supposing, then, that the pigment has been brought with suitable precaution to the condition referred to above, as of the consistency of cream, it is next transferred to a basin (A), stirred up with a large quantity of pure water, allowed to stand a sufficient time for the great bulk of the coloured particles to subside, and then the liquid part of it poured or siphoned off into another vessel. An examination of the matter which is ultimately deposited from this wash-water must decide whether it should be rejected or preserved for use; the older writers are unanimous in directing it to be thrown away. The remaining pigment (in vessel A) is to be well stirred in fresh water, and only the larger and coarser particles allowed to settle, before the coloured water, in which the whole of the finer particles are still suspended, is poured off into another vessel which we will call B. The residue left behind in the first vessel being generally trifling in quantity, and of coarse quality, need not be here further considered, so that we may pass on to the subsequent steps in the treatment of the deposit which will ultimately take place in the second vessel, B. This deposit is treated several times exactly as previously described, the wash-waters being poured off, allowed to settle, and then the deposit thus obtained again stirred up with water and washed. Each washing will carry off a finer quality of pigment from each successive residue; and it only remains to dry each of the final deposits from the several wash-waters by exposing them to a gentle heat and a current of air. For small operations of the kind just described, and where very choice colours are concerned, the apparatus employed in the analysis of clays and soils may be used. An effective form is that designed by Nöbel. It consists of several pear-shaped glass vessels, so arranged that the top of one vessel is in communication with the bottom of the next. Into the highest and smallest vessel, containing the pigment, a stream of water, at an uniform rate and pressure, is conducted, the water entering at the bottom, and flowing out, laden with coloured particles, at the top. Hence a tube conducts it into the bottom of vessel No. 2, which is of larger size. Finally, passing through two other vessels, which are of still larger dimensions, it reaches the final reservoir, which is capable of containing the whole of the wash-waters. After the passage of sufficient water, the liquid in each vessel is allowed to settle, and the several deposits collected and dried. That material which has travelled farthest in suspension, and has reached the largest vessel, will be found to be of the finest quality. Modifications of this plan may easily be devised, but it answers best when the directions of Nöbel are strictly adhered to, especially as to the capacity of the successive receivers, which should be

as the numbers 1 : 8 : 27 : 64. Of course the rate of flow and pressure must be adapted to the particular pigment to be washed. A rough but simple elutriator may be made with a tall ale-glass, a long-necked funnel, a large basin, and a large jar of water with a tap. The substance to be washed is placed in the glass, which is then placed in the basin and filled up with water. A steady stream of water is made to flow from the reservoir, through the long funnel, on to the colour, the strength and height of the stream being so adjusted in each experiment as to carry off only those finer particles of the colour which it is desired to collect. These will be found at the end of the experiment in the basin, which has been placed so as to catch the coloured overflow of the glass.

Before entering into precise details concerning the chemical merits and demerits of the pigments to which we shall refer in this and the succeeding papers, it may not be out of place to assure our readers that Chemistry has not yet rendered to the fine arts a tithe of that service which may be expected of her. It does not suffice for the chemist to present art with new and attractive pigments and dyes, each one more brilliant than the last, and ranging through hues far more numerous than those of the rainbow. The chemist must present these materials in an available form, and with a confident assurance, based on exhaustive experiments, of their thorough permanence. More than this, he must show how to bring to the utmost beauty and durability those approved paints which have long been in use, and then he must further explain those conditions of permanence which affect the oils, varnishes, grounds, and the other materials of art. The chemistry of the numerous processes of painting, ancient and modern, may next engage the attention of the chemist. He ought to throw light also upon important points connected with the conservation and restoration of pictures, and with the materials employed by the architect and sculptor. We hope to have something serviceable to say, on all these points, in the present series of lessons on Chemistry as applied to the Fine Arts.

Beginning with pigments, our remarks on them may naturally commence with those which are used by the painter to represent white. Amongst these, white lead stands in the first place, by reason of its remarkable density and "covering" power. Of course, it is by no means a perfect white, so far as permanency is concerned. Like most compounds of lead, it may be blackened or darkened by sulphuretted hydrogen; and as it slowly combines with a part of the oil with which it is mixed in oil-painting, it is liable to become somewhat translucent in course of time, and to lose a little of that opaque body which is its chief merit. But, on the other hand, the defects of white lead have been exaggerated. In a lecture given before the Society of Arts * it was stated that the blackening action of the sulphur-compounds in the air upon white lead might be shown by mixing some of this white with oil, and submitting the *fresh* mixture to the action of hydro-sulphuric acid gas. But this experiment is not a fair one, since it is notorious that linseed and other fixed oils have a remarkable power, when fresh and liquid, of absorbing this sulphur compound, and conveying it to the lead or other pigments with which they are mixed. As this power is lost when the oil becomes dry or resinified, a test of this kind is quite fallacious, the fact being that white lead ground in oil can be thus preserved almost completely from sulphuration, even in the air of towns. Nor is the fact of the partial combination which ensues between the white lead and the oil without advantage, for in this way the oil hardens more rapidly, and forms a more adherent and homogeneous whole with the ground, the other pigments, and the painting-medium. Then, too, this combination need not take place to any considerable extent, for it is quite possible to replace the oil wholly or partially by other and more inert materials. It is not, however, to be denied that on the grounds before alluded to, and on account also of the poisonous † nature of white lead, an effective substitute for this pigment would prove a desirable addition to the palette of the artist.

White lead is a variable compound of the carbonate and hydrate of this metal; it may be purified by grinding, and long-continued washing, from any basic acetate present. It is of the greatest importance to the purity of the white of the pigment that it should be made* from thoroughly purified metallic lead; the presence of copper, silver, and some other metals, commonly occurring in lead, interferes seriously with the quality of the product. But intentional adulterations of white lead are constantly practised, the material employed as the adulterant being generally finely-ground barytes or heavy-spar, the barium sulphate. No. 1, lead white, or Krems white, is usually pure white lead; No. 2, or Venetian white, contains 50 per cent. of white lead only; No. 3, or Hamburg white, contains 33 parts in 100 of white lead; and No. 4, or Dutch white, no more than 24. When white lead has been used with barytes, the fraud is detected by boiling the pigment with dilute nitric acid, which leaves the barytes undissolved. When whiting has been used, there will be no residue when the sample has been boiled in nitric acid; but if the lead be removed from this solution by hydro-sulphuric acid, the liquid filtered from this black precipitate will give an abundant white deposit, on the addition of ammonium oxalate to it. White lead adulterated with whiting is much less dense and heavy than pure white lead. Other substances occasionally used to adulterate white lead are lead sulphate, chalk, calc spar, gypsum, and china clay. The partial insolubility of all of these, except chalk and calc spar, in boiling dilute nitric acid affords a means for detecting their presence. When white lead has been thoroughly ground and washed, and so far dried as to contain but a small per-centage of moisture, it may be improved in quality as an artists' pigment by being submitted to a considerable pressure in a lever, screw, or hydraulic press. Many other paints, naturally endowed with less opacity and body than white lead, are still more strikingly improved and enriched by this treatment. Before passing to the consideration of other white paints, it may be stated, that the white lead in fresco and tempera pictures, and mural decorations, which has stood the action of the purer and drier air of Italy, rapidly darkens when it is brought into the moist and less pure atmosphere of English towns. White lead demands in this country a more efficient protection than size, etc., can afford.

Zinc white is not a perfect substitute for white lead. It is not poisonous, it does not become discoloured by the action of volatile sulphur compounds, but it possesses 30 per cent. less covering power than white lead. It is, moreover, incapable of entering into combination with the oil mixed with it, being chemically indifferent and insoluble, unlike white lead. Here lies, in fact, one point of inferiority to the latter paint, so that it requires the use of a powerful drier, such as manganese borate, to enable the zinc white and oil to become dry. But, after all, the zinc white remains an extraneous inert body in the oil, when resinified, and the oil never becomes thoroughly tough and hard; it becomes friable, and peels and crumbles off the surface on which it is laid. With other than oleaginous media, it stands much more nearly on a par with lead white. Zinc white is prepared by burning, in a current of air, zinc which ought to be quite free from cadmium, and collecting the product, which is zinc oxide, in a series of chambers. The purest product collects in the chamber farthest from the fire, the contents of the other chambers being mingled with some metallic zinc, which has to be removed by washing, or a repetition of the process of combustion. The freshly-prepared pure oxide should be submitted to hydraulic pressure, and some degree of heat at the same time. When pure, zinc white is perfectly soluble in hydrochloric acid, and does not effervesce during solution. Heated on a piece of porcelain, it becomes yellow when hot, but regains its whiteness on cooling. Its use as a substitute for white lead was proposed as early as 1781, by Guyton Morveau.

Various preparations of lime and its carbonate may be used as white pigments. They possess but little body, and are not generally well adapted for use in oil-painting, owing to the translucency which they then acquire. For mural decoration, several preparations of lime are of great value. The purity of the material, especially its freedom from saline matters and coloured substances, are of chief importance. The fine state of division of the lime whites, and their compression, are matters which require special attention. Whiting, whitening, or levigated

* "Journal of the Society of Arts," 1871, Vol. XIX., pp. 122, 123.

† Drinks containing a little sulphuric acid exercise a remarkable effect in preventing or alleviating the symptoms of lead-poisoning in workmen of white-lead factories.

* For an account of the manufacture of white lead, see Rapport du Jury International, Exposition Universelle de 1855, Vol. I., page 581.

chalk, is nearly pure carbonate of lime, a calcium carbonate. It was the chief white used by the artists of antiquity, and is still employed in mural painting. The purest burnt white marble, some black marbles, and pure burnt limestone, form, when slaked in water, and carefully ground and washed, a substance which is at once a pigment and a material introduced into the ground of works in fresco; it is known as calcium hydrate. When a fine and pure sample of this has been obtained, it is best to keep it in a wet state for some time before using, in closed jars.

Gypsum and alabaster, which are hydrated sulphate of lime, or calcium sulphate, and plaster of Paris, which consists of the same substance, partially dried, have been used as paints, but they are of limited application, and rather treacherous.

Of barytes or barium sulphate, we have before spoken. It is a very abundant and cheap substance, and when pure and finely ground is not without merit as a white pigment. It is not liable to change. It is best prepared artificially, by the mutual action of solutions of a soluble sulphate, as that of sodium, and of barium chloride. It requires, however, when thus made, long-continued washing with boiling water, in order to free it from saline matters.

The ancient colourists possessed, besides white lead, which was not, however, very largely used in pictures, several white pigments which are not now employed. Amongst these may be named the *creta anularia*, a pigment made from powdered white glass, and the African *paractonium*, which appears to have been a kind of white pipeclay.

TECHNICAL DRAWING.—XLVIII.

GOTHIC STONEWORK.

CONCISE SKETCH OF THE HISTORY OF GOTHIC ARCHITECTURE.

THE title "Gothic" is generally understood in the present day to apply to that style of building in which the pointed arch is the most prominent, though not the only feature.

The name has been so variously applied by different authors that the confusion which has resulted renders it sometimes difficult to define the class of buildings meant.

The term "Gothic" appears to have been first brought into use by the Italians, who applied it to all such buildings as were not classic in their character. It seems to have been first used as a term of contempt, by Vasari, an Italian architect, who lived at the commencement of the sixteenth century, who, after speaking of the Greek orders, says, "There is another kind called Gothic, which differs materially, both as to ornament and proportion, from any of modern or ancient date." The next sentence shows how blinded even a great man may become by prejudice :—"So deficient is it in systematic rules, that it may be deemed the order of confusion and inconsistency. The portals of this description of buildings which has so much infested the world are adorned with slender columns entwined with vine-branches, and unequal to sustain the weight, however light, which is placed above them. Indeed, the whole has an air of being made of pasteboard rather than of stone and marble. This style was invented by the Goths, who spread the contagion through Italy. May God deliver every country in future from the adoption of plans that, substituting deformity for beauty, are unworthy of further attention."

Amongst the first writers who appear to have introduced the term into England was Evelyn,* who says: "Gothic architecture is a congestion of heavy, dark, melancholy, monkish piles, without any just proportion, art, or beauty;" and yet on another occasion he describes it as "a fantastical, light species of building," thus showing how little appreciation he had of the characteristics of the style.

Our own Sir Christopher Wren confirms the use of the term "Gothic" as one of contempt, for, after describing certain buildings as "mountains of stone, vast, gigantic buildings, but not worthy the name of architecture," he says, "This we now call the Gothic manner."

"The employment of the term and its application," says Mr. Nicholson, "seem to have arisen from the idea entertained by the Italians that the style of building to which they applied it was introduced by the Goths after their incursion into Italy."

But the Goths did not invent this or, indeed, any style. They had no architecture of their own, and are not only innocent of introducing any new style into Italy, but more than that, they do not seem to have caused any alteration in the old. What changes did take place arose very naturally from the gradual decay of the previous styles, and the growth of feelings and sentiments wholly at variance with the paganism to which the greatest buildings in the classical styles had been dedicated.

In investigating the origin of the name Gothic, we must remember that at the period of the revival of classical architecture in England, the Pointed style had fallen into debasement, and its principles were but little appreciated or understood, and hence the desire to stigmatise it as barbarous. Since then, however, the prejudice has ceased, and the taste for the Gothic style has revived, and thus men are anxious to clear it from any stigma which the term may be thought to imply. Various other names have been given, but certain objections, into which it is not here necessary to enter, apply to each. We therefore retain the original name, as that most generally used.

The historical development of the system, as given in these lessons, is based on the authority of Mr. Rickman, to whose investigations we owe so much. The following is the classification adopted:—

1. *The Norman Style*, which prevailed from the time of William the Conqueror to the end of the reign of Henry II. (1066-1189), distinguished by its arches being generally semi-circular, though sometimes pointed, with bold and rude ornaments.

This style seems to have commenced before the Conquest, but we have no remains *really known* to be more than a few years older.

2. *The Early English Style*, reaching from 1189, the commencement of the reign of Richard I.,* to the end of the reign of Edward I., in 1307, distinguished by pointed arches and long narrow windows, without mullions, and a peculiar ornament, which, from its supposed resemblance to the teeth of a shark or other animal, is generally called the "toothed" ornament.

The reign of Edward I. (1272-1307) was the period of transition from the Early English to the Decorated style. Many of the buildings of this reign belong to the latter style; for instance, the Eleanor crosses, which were all erected between 1290 and 1300, and the style of which is clearly Decorated.†

3. *The Decorated Style*, reaching from 1307 to the end of the reign of Edward III., in 1377, and perhaps from ten to fifteen years longer.‡

This style is distinguished by its large windows, which have pointed arches divided by mullions, and the tracery forming circles and other geometrical figures, or flowing into graceful curves not running directly to the arch of the window. The gradual growth of these forms, which commenced in the Early English period, will be traced as we progress. The ornaments of this period were numerous, and very delicately carved.

4. *The Perpendicular Style*, existing from 1377 to 1546, appears to have been in use, though much debased, as late as 1630 or 1640, but only in additions. The latest complete building was probably erected in the reign of Henry VIII. The name clearly designates this style, for the mullions of the windows and the ornamental panellings run in perpendicular lines, and form a complete distinction from the last style; and many buildings of

* John Evelyn, a distinguished author and traveller, born in the year 1620, died in 1706.

* The reign of Richard I. was the chief period of the transition from the Norman to the Early English style. The change began perhaps a little earlier in a few instances and continued a little later, some buildings of the time of King John being of transition character.

† The transition from the Early English to the Decorated style took place chiefly in the reign of Edward I. The Eleanor crosses belong rather to the latter than the former style.

‡ In the latter part of the long reign of Edward III. the transition from the Decorated to the Perpendicular style began, and was almost completed by the time of the accession of Richard II. Some buildings of the Decorated style may be found of his reign, but the works of William of Wykeham, Westminster Hall, and many other buildings of this period, are of very decided Perpendicular character. Perhaps one of the earliest and best authenticated examples of this transition, showing a curious mixture of the two styles, is Edington Church, in Wiltshire, founded by Bishop William of Edington, in 1352, and consecrated in 1361. The same bishop, who died in 1366, commenced the alteration of Winchester Cathedral into the Perpendicular style, which was continued by William of Wykeham

this period are so crowded with ornament as to destroy the beauty of the design. The carvings are generally very delicately executed.

Of British architecture before the Roman era we have no authentic account; it consisted, most likely, of huts and caves, such as generally form the habitations of uncivilised nations. The ruins of their stupendous public edifices—such as Stonehenge—still remain to us. The Romans, on their arrival, introduced in some degree their own architecture. Some few specimens still remain, of which the gate at Lincoln is the only one retaining its original use. Although some fine specimens of workmanship have been occasionally found, yet by far the greater part of the Roman work was rude, and by no means comparable with the antiquities of Greece and Italy, although executed by the Romans.

When the Romans left the island, it was most likely that the attempts of the Britons were still more rude; and endeavouring to imitate, but not executing on principle, the Roman work, their architecture became debased with Saxon and Early Norman, intermixed with ornaments, perhaps, brought in by the Danes.

After the Conquest, the rich Norman barons erecting very magnificent castles and churches, the execution manifestly improved, though still with much similarity to the Roman mode debased; but the introduction of shafts instead of massive piers first began to approach that lighter mode of building which, by the addition of the pointed arch, and by an increased delicacy of execution and boldness of conception, ripened at the close of the twelfth century into the simple yet beautiful Early English style. At the close of another century this style, from the alteration of its windows, by throwing them into large ones divided by mullions, introducing tracery in the heads of windows, and the general use of flowered ornaments, together with an important alteration in the piers, became the Decorated English, which may be considered as the perfection of English Gothic. This was very difficult to execute, from its requiring flowing lines where straight ones were more easily combined; and at the close of the fourteenth century we find the flowing lines giving way to perpendicular and horizontal ones, the use of which continued to increase until the arches were almost lost in a continued series of panels which, in one building—the chapel of Henry VII.—covered completely both the outside and inside, and the eye, fatigued by the constant repetition of small parts, sought in vain for the bold grandeur of design which had been so nobly conspicuous in the preceding style. The Reformation appears to have put an end for the time to the erection of Gothic edifices, and thus the style became debased and almost entirely lost sight of. The square-panelled and mullioned window, with the wooden-panelled roofs and halls of the great houses of the time of Queen Elizabeth, seem rather a debased English than anything else; but during the reign of her successor the Italian architecture was introduced, first only in columns of doors, and afterwards in larger portions; and this style, which was only fully developed in the reign of James I., is still known as the "Elizabethan," and is considered as the English period of the "Renaissance" or revival.

Architecture has been said to be history written in stone. This is particularly true in relation to Gothic; for the sentiments and feelings of the time are peculiarly impressed on each section of the style. The masons or builders of one age were wholly regardless of the plans, sentiments, or aims of their predecessors. "In every case," says Mr. Wornum, "where a great ecclesiastical work had been suspended, and renewed after intervals, those who have carried on the enterprise have invariably done so regardless of the character of the work already executed. The practice of the day exclusively defined the character of the work, as if the practical education of the handicraftsman, his accidental skill, were the paramount sources of the whole scheme and system of ornamental varieties, each mason working out only such forms as had occupied his time in the years of his apprenticeship."

The general characteristics, then, of the Gothic as an architectural style are these:—It is essentially pointed or vertical in its tendency, its details being for the most part geometrical, in its window tracery, in its openings, in its clusters of shafts and bases, and in its suits of mouldings; but it is only geometrical in its construction, or its form—not in its spirit or motive; and at one period, plants copied directly from Nature were used in beautiful profusion.

Ornamentally, the Gothic is the geometrical and pointed element repeated to its utmost. Its only peculiarities are its combinations of details, at first the conventional and geometrical prevailing, and afterwards these combined, with the elaboration of natural objects in its decoration. Thus, in the finest Gothic specimens we find not only the traditional conventional ornaments, but, in the Decorated period, also elaborate imitations of the plants and flowers growing in the neighbourhood of the work. This is a great feature, but still the most striking point in all true Gothic work is the wonderful elaboration of geometric tracery, vesicas, trefoils, quatrefoils, cinquefoils, with a variety of others which will be described and illustrated farther on. The Norman, and the latter period of that style which constituted the transition to the Early English, cannot be considered as true Gothic, and thus we find no tracery in them, whilst it is so paramount a characteristic of the other three styles that they may be distinguished exclusively by this feature.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XXI.—ROGER BACON.

BY JAMES GRANT.

Roger Bacon, the inventor of gunpowder, the constructor of an air-pump and of reading-glasses, the miracle of the dark age in which he lived, and alleged to have been the greatest mechanical genius the world had then seen since the days of Archimedes, was born at Ilchester, or Ivelchester, in Somersetshire, in the year 1214, in the reign of King John. He commenced his studies at Oxford, from whence he removed to Paris, which at that time was esteemed as the centre of literature; and there he made such brilliant progress in the sciences that he was deemed the glory of the university, and was in high estimation with the most learned of his countrymen, particularly with Robert Greathed, who was Archdeacon of Leicester, and in 1235 Bishop of Lincoln, his future patron. Having taken the degree of doctor, he entered the Franciscan order about the year 1240, either in France, or immediately after his return home. With an ardour that was unremitting he pursued his favourite study of experimental philosophy, and in this pursuit, in instruments, experiments, and scarce MSS., he spent in twenty years the then large sum of £2,000, which was given to him by the University of Oxford to enable him to pursue his researches.

His physical writings show great genius and force of mind. In his treatise "Of the Secret Works of Art and Nature," he shows that a person perfectly acquainted with the manner observed by Nature in her operations would be able to rival her. In another piece, "Of the Nullity of Magic," he points out with clearness and sagacity how weak all its pretences are; and from a perusal of his works, it is evident that Bacon was no stranger to some of the greatest discoveries of the past ages and of the present.

He mentions phosphorus as an unextinguishable fire produced by art; he had an idea of the rarefaction of the air and the structure of the air-pump; he was a master in the science of optics, and has accurately shown the mode of making and using reading-glasses.* He also describes a species of camera obscura, and glasses which can magnify or diminish any object. He asserts that he had seen great numbers of burning-glasses, but that none were ever in use among the Latins until his friend Peter de Mahara Curia applied himself to the manufacture of them; and that an idea of the telescope was not unknown to him is proved from a passage where he says, that he was able "to form glasses in such a manner with respect to our sight and the objects, that the rays shall be refracted and reflected wherever we please, so that we may see a thing under what angle we think proper, either near or at a distance, and be able to read the smallest letters at an incredible distance, and to count even the dust and sand"—a foreshadowing of the microscope. His skill in astronomy was wonderful. He discovered that error which occasioned the reformation of the calendar, and his plan for its correction was followed by Pope Gregory XIII., with this variation, that Bacon would have had the correction to begin from the birth of our Saviour, whereas Gregory's amendment reaches no further back than the Nicene Council; but Bacon's discovery is alleged by Dr. Jebb to have been one of the greatest efforts of human industry.

Bacon's printed works are "Epistola Fratris Rogeri Baconis de Secretis Operibus Artis et Naturæ, et de Nullitate Magiæ," which appeared in Paris in quarto, 1542; "Opus Majus," London, 1733, in folio, edited by Dr. Jebb; "Thesaurus Chemicus," Frankfort, 1603 and 1620. Besides these are many of his MSS. scattered in different libraries and as yet unpublished.

That he knew, invented, and made the discovery of gunpowder is beyond all question, as he tells us that "thunder and lightning may be produced by art; for that sulphur, nitre, and charcoal, which when separate have no sensible effect, when mixed together in due proportion, and closely compressed and fired, yield a *loud report.*"

A more exact and precise description of gunpowder cannot be given in words; yet *fifty-six* years after the time of Bacon, the discovery was assigned to Berthold Schwartz, an Augustinian, who resided at Friburg, in Brisgau, twenty-six miles south of Strasburg. This monk, says Sainte Foix, having put a composition of sulphur and saltpetre in a mortar, it took fire and blew off the stone that covered it with great violence, which led the chemist to think it might be used with great advantage in attacking fortified places. He accordingly added to it a quantity of charcoal to render it more apt to take fire and to continue it. Thus, adds our author, the French were long in possession of this terrible secret, but it was left to the "ferocious temper" of the English to make use of it (!), as they did with such signal success at the battle of Cressy, thus awkwardly admitting that the English were in possession of the secret also. But the same idea may occur to several men. Thus Marcus Græcus, in his "Liber Ignium," describes a composition for fireworks, of 2 lb. of charcoal, 1 lb. of sulphur, and 6 lb. of saltpetre. Jealousy has always caused the French to ignore the existence of Bacon; hence, in the "Dictionnaire Militaire," Vol. III., it is curtly stated that "la poudre à canon a été inventée par Bertold Schuartz, Cordelier Allemand, grand Alchymiste en 1330 sous Philippe VI. de Valois."

Cannon were first used by the Danes in 1354, and by the Venetians in 1366 at the siege of Chioggia, in Lombardy, when the Genoese brought with them two small pieces of artillery, the use of which rendered the reduction of the place easy and expeditious. Eight years after the alleged discovery by Berthold Schwartz, and sixty-four years after the time when Bacon wrote of it, the registers of the Chamber of Accounts, as quoted by Du Cange and Père Daniel, would seem to prove that in 1338 "cannon-powder" was made use of in France; thus, though Schwartz was not the first inventor of the said powder, he may very probably have been the first who recommended its adoption in military matters; and the account of the manner of his acquiring a knowledge of its composition and effect, and the figure and name of *mortars* given to a species of the first artillery, and the use made of them, which was to throw great stones at a certain elevation, much favours this idea. From the first invention of powder by Bacon to the time of Francis I. and Charles V., the machines in use before its discovery, and those which it introduced, were continued in use; but those which owed their rise to the invention of gunpowder have now totally superseded the others; so that of all the weapons of ancient warfare we now retain only the lance and sword, unless we include the long arm-pit dagger or dirk worn by Highland regiments.

Whether powder, which was at first esteemed the most pernicious and destructive invention that the wit of men ever produced, has really been the cause of so much evil as is generally imagined, is a question easily decided if we adopt the remark of Fontenelle ("Histoire de l'Academie des Sciences," ann. 1707), "that whatever renders war more short and decisive renders it less destructive and fatal, and that a much greater number must perish during such long sieges as those related by ancient authors, than in those of the present day, which are beyond conception more short."

The extraordinary talents of Bacon, and his progress in the sciences in an age so unlettered and barbarous, excited the envy of the more ignorant of his brotherhood, whose malice he drew further upon him by the freedom with which he wrote of the clergy in some of his treatises; so they speedily spread abroad a rumour that he was in league with the devil—a common accusation brought against the learned of past times. Among other things, he was accused of having invented a brazen head, which he formed capable of speech: this, after uttering successively, "Time is," "Time was," and "Time is past," the opportunity of catechising it having been neglected, tumbled itself from the stand, and was shattered into countless fragments. Under these and other pretences he was restrained from reading his lectures; his writings were confined to the narrow sphere of his monastery; at length in 1278, when in his sixty-fourth year, he was imprisoned in his cell, but being allowed the use of such MSS. or books as belonged to him, he still proceeded in the pursuit of rational knowledge, correcting his former labours and composing several curious essays.

In 1288, after ten years of close captivity, Jerome de Ascoli, General of his order, who had condemned his doctrines, though a man of great ability, and one who had turned his mind much to the study of philosophy, was elected Pope by the name of Nicholas IV. On this, the poor old inventor resolved to apply to him for a release, and to show alike the usefulness and the perfect innocence of his studies, addressed to him a treatise "On the Means of avoiding the Infirmities of Old Age." What effect this had on the Pope we know not, but Bacon was not discharged until the latter end of his reign, when some English nobles interposed on his behalf. He spent the remainder of his life in the college of his order, where he died in 1294, at eighty years of age, and was buried in the Franciscan church.

Such are the few particulars which diligent researches have been able to discover concerning the life of this extraordinary man. "If knowledge," says Dr. Enfield, "is now too far advanced for the world to derive much information from his writings, respect must, nevertheless, be paid to the memory of a man who knew so much more than his contemporaries, and who, in a dark age, added new lights to the lamps of science."

Though discovered so early in England, no gunpowder would seem to have been manufactured there until the time of Queen Elizabeth, when, according to Rapin, she ordered it to be made at home in 1561, with special reference to the fortification of Berwick and other places along the English border. After that the manufacture of powder steadily increased in England.

In recent times the frauds and failures of contractors engaged to supply this important article of warlike material, led the Government in 1790 to determine upon the establishment of their own powder manufactory, a measure which has been attended with good results, and ensures a better description of powder at a reduced cost. Under the contract system, the regulation charge for a cannon was half the weight of the ball, and the average range was 191 feet; the range of the powder produced by Government in 1858 was 268 feet, and the charge was reduced to one-third the weight of the ball; while more recent experiments at Shoeburyness have far exceeded the most daring ideas of the gunners of even twenty years ago. The standard of quality is regulated by the factory at Waltham Abbey, in Essex. During the early part of the present century, there were three Government manufactories for powder, and their annual produce amounted to above 100,000 barrels. In 1815 two were abolished, and that at Waltham alone retained; and even that was so reduced that in 1840 its produce could not be brought to 3,500 barrels, and supplies had to be obtained by contract. From that time up to the commencement of the Crimean war, many important improvements were introduced, and works were projected to raise the produce to 20,000 barrels annually—insufficient, however, for the wants by sea and land in time of war. The consumption of powder during the siege of Sebastopol alone exceeded 100,000 barrels, of which 32,000 had to be purchased from Belgium and America.

Whenever 500 barrels have accumulated within the factory grounds, they are dispatched by water to the bomb-proof magazines at Purfleet, on the Thames. A large quantity of new machinery was introduced at Waltham Abbey, which, during the Crimean war, in addition to an extensive saltpetre refinery, and a range of ovens, contained twenty-one water-wheels, five steam-engines, and seventy-two machines of various descriptions.

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